National Hydroelectric Power Resources Study

Volume VIII
September 1981

Environmental Assessment —

Prepared by:
INTASA, Inc.
1030 Curtis Street
Menlo Park, California 94025

Under Contract to:
The U. S. Army Engineer
Institute for Water Resources
Casey Building
Fort Belvoir, Virginia 22060

Contract Number DACW72-80-C-0002

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER Volume VIII	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) National Hydroelectric Power Resources Study Environmental Assessment	5. TYPE OF REPORT & PERIOD COVERED Final Report
	6. PERFORMING ORG. REPORT NUMBER IWR - 82 - H - 8
7. AUTHOR(s) WRSC, IWR INTASA, INC., EDAW, INC., and SVERDRUP &PARCEL and Associates, INC.	8. CONTRACT OR GRANT NUMBER(s) DACW72 - 80 - C - 0002
9. PERFORMING ORGANIZATION NAME AND ADDRESS INTASA, INC., EDAW, INC., and SVERDRUP & PARCEL Menlo Park, CA.	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS WRSC - Institute for Water Resources Casey Building Ft. Belvoir, VA 22060	12. REPORT DATE September 1981
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hydroelectric Power	Dams
Environmental Impacts	Run-of-River
Mitigation	Storage
Technology	Fishways

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the results of a broad environmental assessment of possible future hydropower additions at existing dams and undeveloped sites in the United States. The study was part of the National Hydroelectric Power Resources Study (NHS) conducted by the U.S. Army Corps of Engineers and managed by the Corps' Institute for Water Resources.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

National Hydroelectric Power Resources Study
U.S. Army Corps of Engineers

FINDING OF NO SIGNIFICANT IMPACT

I have reviewed the Environmental Assessment (EA) prepared for the National Hydroelectric Power Resources Study (NHS) and have determined that the nature and extent of the environmental consequences resulting from the study will not cause significant local, regional, or national impacts on the environment. The NHS final report identifies about 2000 best candidate sites for possible future planning studies. The report does not contain recommendations for development of hydroelectric power facilities at these sites. The EA analyzed the generic environmental impacts of different types of hydroelectric power facilities, evaluated potential environmental impacts by region based on NHS estimates of potential future sites, and assessed existing environmental planning procedures and legislation affecting hydroelectric power development. An extensive public involvement and coordination effort was undertaken as part of the NHS. The study is not intended to replace traditional project planning, but to provide a national overview to supplement the existing planning and appropriation process. All potential best candidate sites will be evaluated on an individual basis before any proposals for development are made. The EA satisfies the procedural requirements of the National Environmental Policy Act (NEPA) and the Council on Environmental Quality regulations (40CFR 1500-1508) for purposes of this initial study. Because the EA does not indicate that the proposed action is a major Federal action significantly affecting the human environment, I have determined that an Environmental Impact Statement is not required.

Forrest T. Gay III

FORREST T. GAY, III
Brigadier General, USA
Acting Director of Civil Works

United States Army Corps of Engineers

National Hydroelectric Power Resources Study
Environmental Assessment

Institute for Water Resources
Kingman Building
Fort Belvoir, Virginia 22060

March 1982

PREFACE

This report presents the results of a broad environmental assessment of possible future hydropower additions at existing dams and undeveloped sites in the United States. The study was part of the National Hydroelectric Power Resources Study (NHS) conducted by the U.S. Army Corps of Engineers and managed by the Corps' Institute for Water Resources.

The preparation of this report was the responsibility of the Institute for Water Resources and was written by IWR staff. Major contributions were made under contract by INTASA, Inc. in association with EDAW, Inc. and SVERDRUP & PARCEL and Associates Inc.

Three public workshops, two in Washington, D.C. and one in Portland, Oregon, were conducted to solicit comments and other information for this study and other parts of the NHS. These concerns and comments of the public and incorporated herein.

CONTENTS

PREFACE ____ II
TABLE OF CONTENTS ____ III
LIST OF ILLUSTRATIONS ____ V
LIST OF TABLES ____ IX
APPENDICES ____ X

EXECUTIVE SUMMARY ____ 1

CHAPTER 1 INTRODUCTION ____ 1-1
- A. Purpose ____ 1-1
- B. Objectives ____ 1-1
- C. Approach ____ 1-2
- D. Report Organization ____ 1-3

CHAPTER 2 HYDROPOWER TECHNOLOGY ____ 2-1
- A. Technology Overview ____ 2-1
- B. Mitigation Technology ____ 2-15
- C. Classification of Hydropower Configurations ____ 2-23

CHAPTER 3 GENERIC ENVIRONMENTAL IMPACTS ____ 3-1
- A. Relationships Between Hydropower Configurations and Environmental Impacts ____ 3-1
- B. Classification of Impacts ____ 3-1
- C. Discussion of Environmental Impacts ____ 3-13
- D. Conclusions About Hydropower ____ 3-27
- E. Hydropower Contrasted With Other Energy Sources ____ 3-29

CHAPTER 4 REGIONAL ENVIORNMENTAL PROFILES ____ 4-1
- A. Introduction ____ 4-1
- B. Pacific Northwest Region ____ 4-3
- C. Pacific Southwest Region ____ 4-9
- D. Rocky Mountain Region ____ 4-14
- E. Plains Region ____ 4-24
- F. Central Region ____ 4-30
- G. North Atlantic Region ____ 4-35
- H. South Atlantic Region ____ 4-42

CHAPTER 5 REGIONAL ENVIRONMENTAL ASSESSMENT ____ 5-1
- A. Introduction ____ 5-1
- B. Projected Regional Development ____ 5-1
- C. Regional Assessment of Hydropower Development and Environmental Impacts ____ 5-14

CHAPTER 6 HYDROPOWER PLANNING AND ENVIRONMENTAL LEGISLATION ____ 6-1
- A. History of Change ____ 6-1
- B. Federal Versus Non-Federal Development ____ 6-9
- C. Environmental Legislation and Hydropower Development ____ 6-19

CHAPTER 7 MITIGATION AND CUMULATIVE IMPACTS ____________________ 7-1
A. Introduction ____ 7-1
B. Mitigation ____ 7-1
C. Selected Mitigation Techniques ________________________ 7-2
D. Implementation ______________________________________ 7-5
E. Conclusions About Mitigation __________________________ 7-7
F. Cumulative Impacts ___________________________________ 7-9

BIBLIOGRAPHY

LIST OF ILLUSTRATIONS

Figure 2.1 MAJOR TYPES OF DAMS 2-3

Figure 2.2 STORAGE HYDROELECTRIC OPERATION—PLAN VIEW 2-4

Figure 2.3 TYPICAL STORAGE HYDROELECTRIC PROJECT—PROFILE VIEW 2-5

Figure 2.4 RUN-OF-RIVER HYDROELECTRIC OPERATION—VIEW 2-6

Figure 2.5 TYPICAL RUN-OF-RIVER HYDROELECTRIC PROJECT—PROFILE VIEW 2-7

Figure 2.6 IMPULSE TURBINE 2-10

Figure 2.7 SCHEMATIC DIAGRAMS OF FRANCIS AND PROPELLER/KAPLAN TURBINES 2-11

Figure 2.8 SCHEMATIC DIAGRAM OF MIXED AND CROSS-FLOW TURBINES 2-13

Figure 2.9 TYPICAL WEIR FISHWAY—FRONT VIEW 2-16

Figure 2.10 WEIR FISHWAY—SIDE VIEW 2-17

Figure 2.11 SUBMERGED ORIFICE FISHWAY—SIDE VIEW 2-18

Figure 2.12 OVERFLOW SPILLWAY 2-22

Figure 2.13 HYDROPOWER CLASSIFICATION SYSTEM USED BY THE U.S. ARMY CORPS OF ENGINEERS 2-24

Figure 2.14 ALTERNATIVE HYDROPOWER CLASSIFICATION SYSTEMS 2-25

Figure 2.15 DERIVATION OF HYDROPOWER CLASSIFICATION CATEGORIES 2-28

Figure 2.16 HYDROPOWER CONFIGURATION CLASSIFICATION SYSTEM FOR ENVIRONMENTAL ASSESSMENT 2-29

Figure 3.1 EXAMPLE OF CHAIN OF RELATIONSHIPS BETWEEN HYDROPOWER DEVELOPMENT AND ENVIRONMENTAL IMPACTS 3-2

Figure 3.2 MAJOR CLASSES OF HYDROPOWER IMPACTS 3-4

Figure 3.3 ANADROMOUS AND INLAND MIGRATORY FISHERIES AND RESTORATION AREAS 3-8

Figure 3.4 RELATIVE RANGES OF ENVIRONMENTAL ACCEPTABILITY FOR HYDROPOWER CONFIGURATIONS 3-28

Figure 3.5 COMPARISON OF RISK (PUBLIC AND OCCUPATIONAL) AMONG ENERGY TYPES 3-29

Figure 3.6 COMPARISON OF ENVIRONMENTAL CHARACTERISTICS AMONG ENERGY TYPES 3-32

Figure 4.1 REGIONAL STUDY AREAS 4-2

Figure 6.1a INSTALLED GENERATING CAPACITY OF THE ELECTRIC UTILITY INDUSTRY 1920-1978 6-4

Figure 6.1b HYDROPOWER'S SHARE OF TOTAL ELECTRIC UTILITY INDUSTRY GENERATING CAPACITY 6-4

Figure 6.2 CONVENTIONAL HYDROELECTRIC CAPACITY BY CLASS OF OWNERSHIP, 1920-1977 6-5

Figure 6.3 FERC APPLICATIONS FOR LICENSES AND PRELIMINARY PERMITS 6-7

Figure 6.4 CORPS PROCESS 6-14

Figure 6.5 FERC PROCESS 6-16

Figure 7.1 MAP OF THE COLUMBIA RIVER SYSTEM SHOWING AREA ACCESSIBLE TO ANADROMOUS FISH HISTORICALLY AND IN 1970 7-13

Figure 7.2 COMPARISON OF COLUMBIA FISH CATCH AND CUMULATIVE IMPACT INDICES 7-15

Figure A.1 RELATIVE SCHEDULE OF ACTIONS FOR HYDROPOWER DEVELOPMENT A-4

Figure B.1 ALTERNATIVE HYDROPOWER CLASSIFICATION SYSTEMS B-3

Figure B.2 ARMY CORPS OF ENGINEERS DIVISIONS AND DISTRICTS B-4

Figure B.3 SUMMARY OF IMPACT ISSUES BY ALTERNATIVE HYDROPOWER CLASSIFICATION DEFINITIONS FOR FOUR CORPS DISTRICTS B-6

Figure D.1 NATIONAL ELECTRIC RELIABILITY COUNCIL REGIONS D-3

Figure D.2 FISH AND WILDLIFE SERVICE REGIONS D-3

Figure D.3 WATER RESOURCES REGIONS D-3

Figure D.4 ECOREGIONS OF THE UNITED STATES D-4

Figure D.5 NATIONAL HYDROELECTRIC POWER RESOURCES D-4

Figure D.6 REGIONAL STUDY AREAS D-6

Figure E.1 SAMPLE QUESTIONNAIRE (PACIFIC NORTHWEST) ____________ E-3

Figure F.1 MATRIX OF GENERIC HYDROPOWER IMPACTS RELATED TO TERRESTRIAL ECOLOGY ____________ FO-1

Figure F.2 MATRIX OF GENERIC HYDROPOWER IMPACTS RELATED TO WATER QUALITY AND USE ____________ FO-2

Figure F.3 MATRIX OF GENERIC HYDROPOWER IMPACTS RELATED TO AQUATIC ECOLOGY ____________ FO-3

Figure F.4 MATRIX OF GENERIC HYDROPOWER IMPACTS RELATED TO LAND USE AND RECREATION ____________ FO-4

Figure H.1 CUMULATIVE RATIO OF IMPOUNDED WATER TO LENGTH OF RIVER ALONG THE COLUMBIA ____________ H-8

Figure H.2 CONNECTICUT RIVER STREAMFLOW DURING INTENSE DROUGHT OF JULY-AUGUST 1964 SHOWING DEVIATION FROM MINIMUM FLOW STANDARDS ____________ H-13

Figure H.3 MAJOR STEPS IN PROCEDURE FOR EVALUATING CUMULATIVE IMPACTS ____________ H-14

Figure H.4 RELATIONSHIP BETWEEN INDICES AND IMPACTED RESOURCES __ H-16

Figure H.5 CLASSIFICATION OF RESOURCES IMPACTED BY HYDROPOWER DEVELOPMENT ____________ H-17

Figure H.6 GENERALIZED ALTERNATIVE RELATIONSHIPS BETWEEN HYDRO-POWER DEVELOPMENT AND LOSS OF A RESOURCE ____________ H-20

Figure H.7 THEORETICAL RELATIONSHIPS BETWEEN CUMULATIVE HYDRO-POWER DEVELOPMENT, LOSS OF IMPACTED RESOURCE AND SIGNIFICANCE OF IMPACT ____________ H-23

LIST OF TABLES

Table 3-1 SUMMARY OF ENVIRONMENTAL CHARACTERISTICS BY ENERGY TYPE ____ 3-31

Table 5-1 POTENTIAL HYDROPOWER DEVELOPMENT BY REGION ____ 5-2

Table 5-2 1980 ELECTRIC GENERATION BY FUEL TYPE (%) ____ 5-10

Table 5-3 1980 INSTALLED ELECTRIC GENERATING CAPACITY BY FUEL TYPE (MW) ____ 5-11

Table 5-4 PROJECTED ELECTRIC GENERATION BY FUEL TYPE IN THE YEAR 2000 (%) ____ 5-12

Table 5-5 PROJECTED INSTALLED CAPACITY BY FUEL TYPE IN THE YEAR 2000 (MW) ____ 5-13

Table 5-6 PROBABLE REPLACEMENT SOURCES OF ENERGY FOR HYDROPOWER, BY REGION ____ 5-15

Table 6-1 ROLES OF FEDERAL AGENCIES IN HYDROPOWER DEVELOPMENT ____ 6-10

Table 6-2 SUMMARY OF MAJOR ENVIRONMENTAL POLICIES AFFECTING HYDROPOWER DEVELOPMENT ____ 6-21

Table A-1 CONSTRUCTION AND OPERATION ACTIONS ASSOCIATED WITH HYDROPOWER DEVELOPMENT ____ A-3

Table E-1 SUMMARY OF QUESTIONNAIRE RESULTS ____ E-4

Table H-1 ESTIMATES OF CONTROL OF STREAMFLOW FOR MAJOR RIVER BASINS ____ H-6

TECHNICAL APPENDICES

Appendix A	DEFINITIONS FOR CONSTRUCTION AND OPERATION ACTIONS ___	A-1
Appendix B	METHODOLOGY FOR SELECTING THE CLASSIFICATION SYSTEM __	B-1
Appendix C	DESCRIPTION OF HYDROPOWER CONFIGURATIONS _____________	C-1
Appendix D	SELECTION OF REGIONAL STUDY AREAS ____________________	D-1
Appendix E	REGIONAL QUESTIONNAIRES ______________________________	E-1
Appendix F	ENVIRONMENTAL MATRICES _______________________________	F-1
Appendix G	ENVIRONMENTAL LEGISLATION ____________________________	G-1
Appendix I	DESCRIPTION OF REPLACEMENT ENERGY TECHNOLOGIES _______	I-1

EXECUTIVE SUMMARY

Introduction

This report presents a broad assessment of the likely environmental impacts from future hydropower development in the United States. The assessment was part of the National Hydroelectric Power Resources Study (NHS) authorized by Congress and conducted by the Corps of Engineers. The NHS evaluated the potential for additional hydropower and prepared a plan to guide future studies of feasible sites. The environmental assessment examined the generic environmental impacts of different types of hydropower facilities, evaluated potential environmental impacts by region based on NHS estimates of likely future development, and assessed the effectiveness of environmental studies of hydropower impacts at individual sites.

Generic Environmental Impacts

The approach used to identify and examine generic environmental impacts was to first develop a system to classify hydropower projects to accurately describe engineering aspects while illustrating environmental differences. Once the classification was defined, the environmental impacts of each type of hydropower project were summarized.

The classification system categorized hydropower sites by three main parameters--site status (undeveloped or existing dam site); type of operation (run-of-river, storage, or conduit); and scale or size of the project. The system was used in matrix form to summarize the generic environmental impacts. Figure 1 depicts the classification system.

The environmental impacts of hydropower development result from actions that change the physical or social conditions of an area. The two principal actions that result from hydropower development are (1) construction, as in

	DEFINITION OF HYDROPOWER																	
TYPE OF OPERATION	RUN-OF-RIVER						STORAGE						CONDUIT					
SITE STATUS	UNDEVELOPED			EXISTING DAM OR CHANNEL			UNDEVELOPED			EXISTING DAM OR CHANNEL			UNDEVELOPED			EXISTING DAM OR CHANNEL		
SCALE (MW)	< 5	5 – 30	> 30	> 5	5 – 30	> 30	< 5	5 – 30	> 30	< 5	5 – 30	> 30	< 5	5 – 30	> 30	< 5	5 – 30	> 30

Figure 1 HYDROPOWER CONFIGURATION CLASSIFICATION SYSTEM FOR ENVIRONMENTAL ASSESSMENT

building a powerhouse, and (2) operation, as in raising the level of a reservoir by storing water. Changed conditions are the resultant chemical, physical, biological, or cultural modifications to the environment. Primary impacts result directly from changed conditions; secondary impacts, on the other hand, are social responses to the primary impacts. To soften either type of impact, operational or institutional techniques, called mitigation measures, can be applied. Figure 2 shows an example of the chain of environmental relationships for the operational action of releasing water through turbines.

Hydropower development entails as many as 14 major construction actions and 5 operational actions that, in turn, can cause at least 53 changed conditions that can then generate more than 300 primary and secondary impacts. These construction and operational actions, changed conditions and primary and secondary impacts have been summarized in a set of matrices (Appendix F).

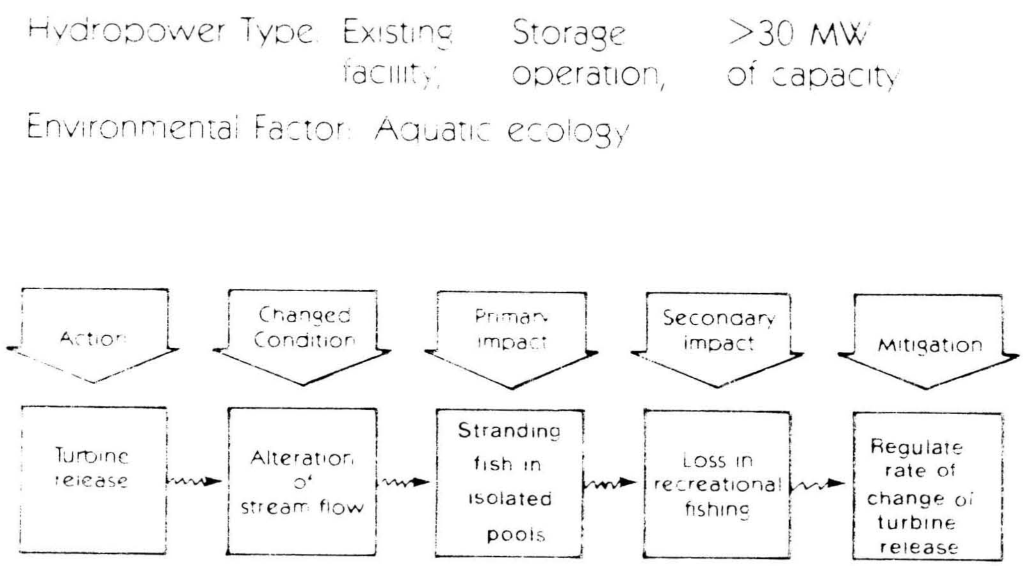


Figure 2 EXAMPLE OF CHAIN OF RELATIONSHIPS BETWEEN HYDROPOWER DEVELOPMENT AND ENVIRONMENTAL IMPACTS

The use of the matrices details the differences among the many categories of hydropower development. The principal differences, however, depend on only a few key characteristics (Figure 3). Some impacts can be expected from any type of hydropower activity, no matter how small--for example, the construction of transmission lines and a resultant loss of wildlife habitat. Undeveloped sites--that is, projects that require the construction of a new dam and a reservoir--entail another major class of hydropower impacts, including the transformation of a river section to a reservoir, the flooding of agricultural land, and the potential blocking of migratory fish runs. Facilities operated to meet peak power demands, on the other hand, continually change reservoir levels and alter downstream flows, generating a range of impacts unique to so-called "peaking facilities." The drawdown zone associated with peaking operations inhibits warmwater fish from spawning and disrupts the ecology of the reservoir. Fluctuations downstream can alternately strand fish in isolated pools and flood habitat for waterfowl.

Conduits are a special category. Some conduits are part of irrigation or other water distribution systems. Little impact is associated with hydropower development in these man-made systems. Other conduits are used at dams on rivers to increase head by bypassing long stretches of stream. This type of conduit can dewater parts of a stream and affect fish and wildlife.

Finally, some impacts result primarily from the large size of projects. For example, temperature stratification in reservoirs, which damages water quality downstream, is a more serious problem with large, deep reservoirs than with small, shallow ones (the deeper the reservoir, the greater the stratification, and, thus, the greater the problems downriver). As another example, the supersaturation of atmospheric gas, which can be fatal to fish, results only when flows pass over high spillways and plunge into deep pools.

In summary, this generic environmental assessment of hydropower provides an understanding of the relationships among types of projects, their associated actions, and the resultant effects on the environment. The study team has attempted to present information concisely to distill the basic

LARGE-SCALE

ACTIONS

- Switchyard Construction
- Relocation of Roads, Rail Lines, and Structures

IMPACTS

- Dam Safety Hazard
- Reservoir Stratification and Water Quality Problems
- Gas Supersaturation
- Delay in Fish Migration
- Potential for Flatwater Recreation, Flood Control, and Water Supply
- High Reservoir Evaporation Rates

PEAKING

ACTIONS

- Reservoir Storage and Release to Increase Value of Energy

IMPACTS

- Daily, Seasonal Downstream Flow Alteration
  - Dewatering and Stranding Fish
  - Change in Riparian Vegetation
  - Flooding Waterfowl Habitat and Eliminating Nesting Islands
- Daily, Seasonal Reservoir Level Fluctuation
  - Visual and Recreational Nuisance of Exposed Drawdown Zone
  - Loss of Warmwater Spawning Grounds
  - Transport of Nutrients in Shallow Water to Deeper Water
  - Bank Erosion

CONDUIT

ACTIONS

- Stream Diversion

IMPACTS

- Dewatered Stream
- Disruption of Deer and Elk Migration

UNDEVELOPED

ACTIONS

- Dam Construction
- Reservoir Clearing

IMPACTS

- Change from River to Lake Environment
  - Loss of Riparian Edge
  - Change in Aquatic Plant and Fish Species
- Blocked Migratory Fish Runs and Loss of Spawning Grounds
- Trapped Nutrients and Sediment
- Altered Downstream Flow Regime
- Alteration of Water Temperatures
- Conversion of Land Uses
  - Loss of Wilderness and Whitewater Recreation
  - Loss of Wetlands
  - Loss of Agricultural Lands
  - Loss of Archaeological and Historic Sites

ALL HYDROPOWER

ACTIONS

- Excavation and Powerhouse Construction
- Transmission Line Right-of-Way Clearing and Line Construction
- Power Generation
- Maintenance, Including Dredging

IMPACTS

- Visual Intrusion Caused by Powerhouse and Transmission Lines
- Fish Mortality from Turbine Passage
- Potential Loss of Critical and Other Wildlife Habitat from Right-of-Way Clearing
- Increased Demand for Local Services from Construction and Maintenance Workforce
- Potential Release of Sediment and Toxic Substances
- Recreational Hazard

Figure 3 MAJOR CLASSES OF HYDROPOWER IMPACTS issues and allow the analyst to distinguish the important qualitative differences among major classes of hydropower projects. Still, site specific studies will be required to determine the environmental impacts of most sites.

Hydropower Potential

As mentioned, the Corps has conducted, as part of the NHS, an inventory of potential hydropower sites throughout the nation. The 60,000 sites originally identified were screened by the Corps to eliminate those that had any significant economic, environmental, legal, or institutional problems. For example, identified sites located in wilderness areas or along stretches of wild and scenic rivers were eliminated from consideration as feasible sites. The inventory of feasible sites now number about 1900.

Figure 4 shows a summary of the number of sites and associated capacity and energy, identified by the NHS as being feasible for future hydropower development. Although the NHS only recommends that these sites should be subject to further detailed study prior to a decision to develop, the totals are a good estimate of likely future hydropower development by the year 2000.

Most sites are located at existing dams (1350 v. 550), but most of the potential capacity and energy is at undeveloped sites. Other things being equal, new facilities at undeveloped sites will create more environmental impact than additions at existing dams.

Over 50 percent of the potential sites are likely to be operated as storage projects. These sites will contribute about 65 percent of the additional capacity associated with all sites. Thus, the majority of additional sites and additional capacity will be storage operations.

By far, most sites are 30 MW or less in capacity (1600 v. 300). However, most of the capacity (34,000 MW v. 11,000 MW) is associated with the larger projects. The predominance of capacity at large complex sites accounts for

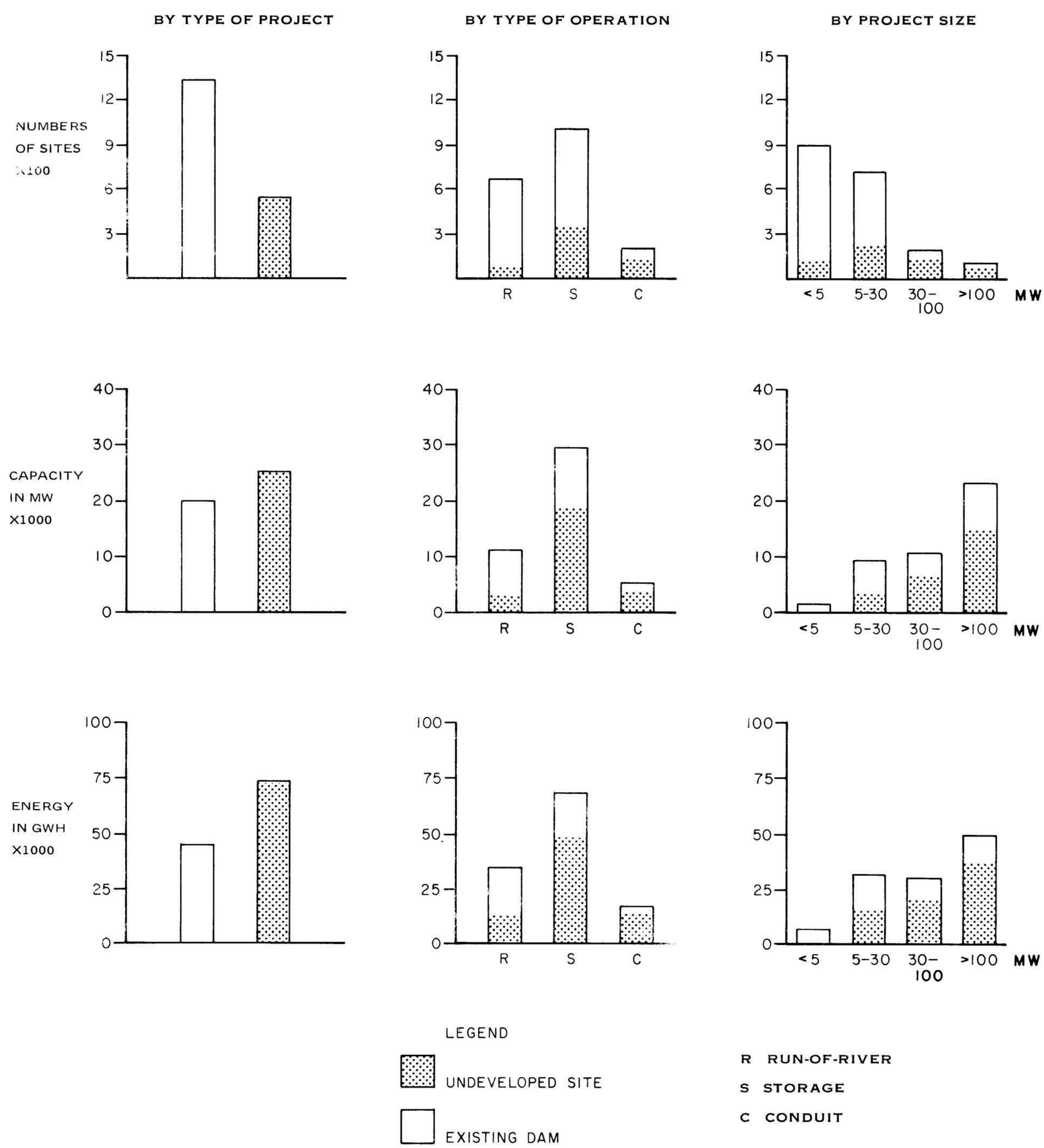


FIGURE 4: CHARACTERISTICS OF THE MOST SUITABLE HYDROPOWER SITES AS DETERMINED BY THE NHS.

part of the difficulty in conducting a general assessment of hydropower sites without site specific analysis.

A great imbalance exists between the number of sites and estimated capacity among regions of the country. This is particularly true in the North Atlantic region, which has nearly one-third of the sites but only 12 percent of the capacity. Conversely, the Pacific Northwest holds about 32 percent of the nationwide capacity, but less than 20 percent of the sites. To provide environmental perspective, these estimates must be evaluated in light of the predominant type of hydropower projected for the region. Of the hydropower potential in the Pacific Northwest, large storage facilities at undeveloped sites, most likely constructed to provide peaking power, are expected to predominate. Exactly the opposite situation prevails in the North Atlantic region; there, the primary potential is for retrofitting existing dams for small-scale, run-of-river operations. As will be noted, environmental effects differ widely between these two distinct types of hydropower.

Regional Assessment

The specific environmental impacts of a hydropower facility depend on the design of the project and the characteristics of the site. Nevertheless, in a generic sense, some common concerns and unique regional differences are exhibited throughout the country. Two adverse aquatic impacts are of particular and uniform concern--fluctuating water levels in reservoirs and changing streamflows below the dam. Each can cause pervasive and sometimes permanent disruption to the aquatic ecosystem. Moreover, these impacts can be caused with regularity at both retrofitted and new hydropower projects that have no particularly unusual characteristics about them. However, the other significant environmental issues tend to recur within each region, yet remain distinct from those in other regions (Figure 5). Some of the major regional differences are discussed briefly in the following paragraphs.

Only in the Pacific Northwest is hydropower the principal source of electricity. There, several large federal projects on the Columbia River are

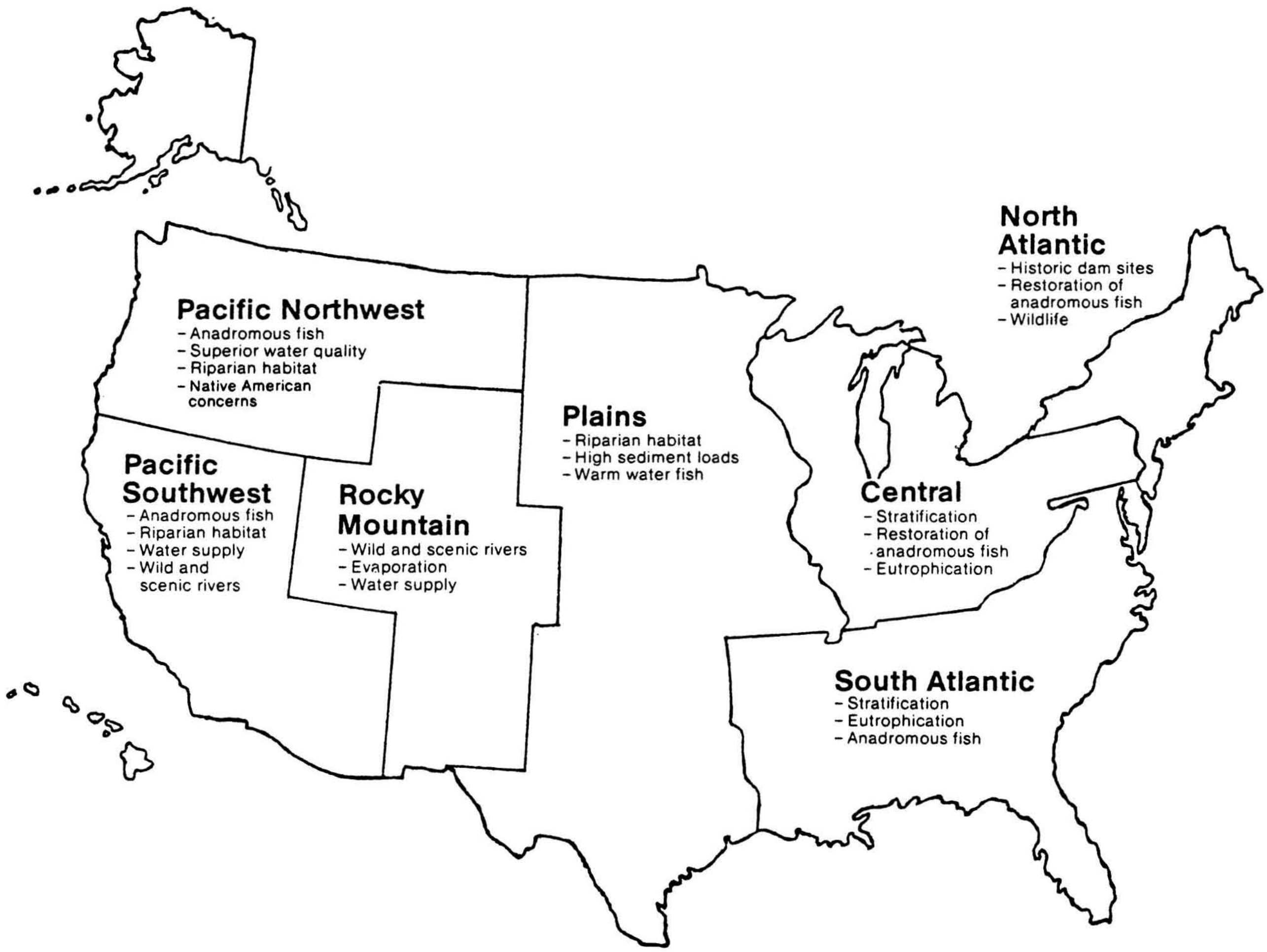


Figure 5 KEY HYDROPOWER ISSUES, BY REGION

coordinated to meet peak demands. Their impact on major anadromous fish runs of salmon and steelhead trout has been significant and the focus of extensive study. Mitigation measures include improved fishways, spillway deflectors, and regulated releases to assist the migration of anadromous fish. Several new, large storage plants are projected for the region, however, and could hamper efforts to improve the region's anadromous fishery. Such facilities typically cause the most severe environmental impacts of all hydropower types.

Most of the existing and projected hydropower in the Pacific Southwest lie within California. There, the plight of anadromous fish, loss of riparian habitat, and conflicts over water supply and wild and scenic rivers are key issues. Projected, new, mid-sized storage projects may also adversely affect anadromous fish and riparian habitat. Development of California's small-scale retrofit projects will probably raise less environmental concern.

In contrast, the numerous possibilities for small-scale projects in the North Atlantic region could conflict with the cultural value of historic dam sites, and must also be coordinated with efforts to restore anadromous fish runs in New England. However, environmental effects of the proposed development are expected to be minor.

Overall, the regional assessment provides a clearer understanding of the significance of the impacts of hydropower. The physiography and power supply system of a region determines the most suitable type and feasible level of hydropower development to be undertaken. These considerations, combined with the ecological characteristics of the region, reveal the key environmental issues.

Replacement Sources of Energy

If regional goals to expand hydropower are not achieved, conventional sources of energy, such as coal, nuclear power, and oil, would have to be expanded. They are the logical replacements because they are dependable and can satisfy requirements for constant (or "firm") power. At present, oil and natural gas are the primary sources of peaking power in the United States. To reduce a potential energy deficit, some regions might be forced to forego plans to decrease reliance on oil and natural gas, or to extend the life of outdated and inefficient plants otherwise scheduled to close. However, with adequate reservoir capacity and control of releases, hydropower can be an excellent source of peaking power. But, on the negative side, large, peaking hydropower units also may cause severe environmental impacts, particularly as a result of rapid fluctuations in water levels, both in the reservoir and downstream from the dam.

Some of the environmental characteristics of other sources of energy are compared with hydropower in Figure 6. Note that hydropower has negligible emissions to air and water, in stark contrast to other energy types. However, most of the environmental problems associated with these sources of energy cannot be evaluated simply by measuring tons of emissions. Large-scale hydropower facilities, for example, may induce profound changes in the ecosystem, such as significantly altered flow regimes, the blocking of access to upstream spawning areas, substantial loss of wildlife habitat or agricultural land, and the release of poor-quality water from stratified reservoirs. At the same time, however, coal-fired plants can discharge sulfur, ash, nitrogen oxides, and various hydrocarbons to the air, degrading its quality for miles around. Nuclear plants arouse concern for public safety and for the transport and disposal of fuel and waste. Oil is an increasingly scarce and expensive resource whose combustion can pollute the air. Stated

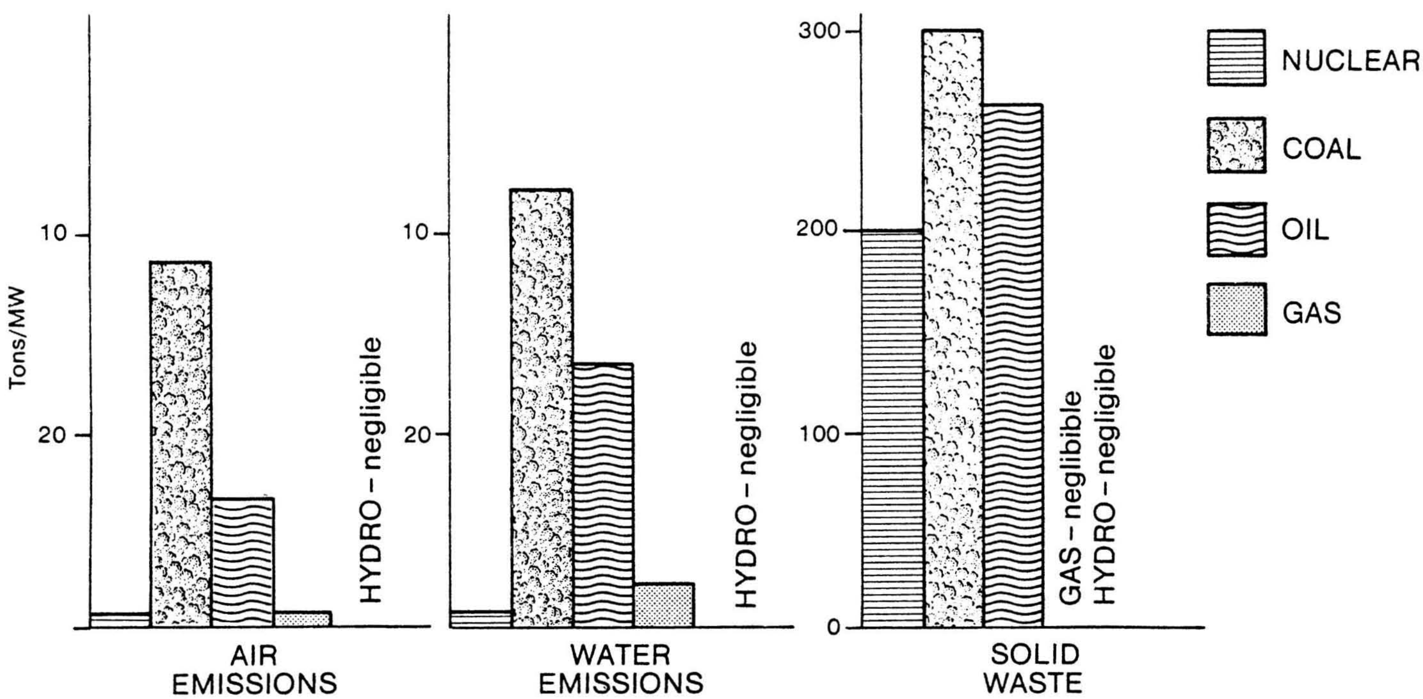


Figure 6 COMPARISON OF ENVIRONMENTAL CHARACTERISTICS AMONG ENERGY TYPES

simply, every kind of energy resource has a unique environmental cost. The selection of one source of energy over another is rarely clearcut, but, to some extent, is linked to the particular environmental costs that people in the region are willing to bear.

Environmental Planning and Policy

A complex web of environmental regulations and overlapping authority awaits the developer of a hydropower resource. Both the federal and non-federal developer are confronted with requirements to meet goals for environmental quality, and, if necessary, to mitigate unacceptable environmental impacts. Procedures that have evolved from legislation, such as the Fish and Wildlife Coordination Act, the Endangered Species Act, the Wild and Scenic Rivers Act, and the National Environmental Policy Act, govern the amount of dredging that can take place, the timing and volume of release waters, and the particular attributes of the fishery that should be preserved.

The approval process for federal and non-federal developers differs markedly, and may ultimately affect the speed at which the anticipated projects can be constructed (Figure &). Historically, federal developers such as the Corps of Engineers and the Bureau of Reclamation have had primary responsibility for developing large, multipurpose water resources projects that may or may not include hydropower as an ancillary feature. Such projects require substantial and time-consuming review and evaluation. Furthermore, federal developers must also follow a detailed evaluation process that requires complex accounting of economic, environmental, and social costs and benefits. Typically, a large federal project requires 15 to 20 years from conception to completion.

Non-federal developers (including state and local agencies) must obtain a license from the Federal Energy Regulatory Cmmission (FERC). In this case, the developer is required to coordinate with all pertinent state and federal agencies (much the same as the federal developer) and to supply FERC with documentation that the necessary permits have been received, and that

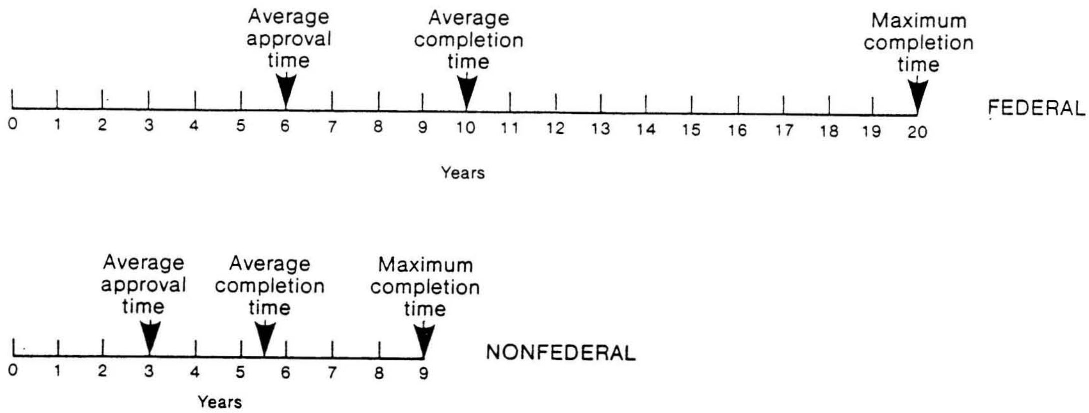


Figure 7 RANGE OF TIME REQUIRED TO COMPLETE FEDERAL AND NONFEDERAL HYDROPOWER PROJECTS

environmental impacts are minor or that some mitigation measures have been taken. The time required for approval averages from one to six years; recent changes to streamline the process are expected to reduce the approval time even further for small facilities at existing dams. Licenses are rarely denied, although the developer may be required to add certain facilities, such as fishways, artificial spawning areas, or fish hatcheries, or to change operation to reduce the expected impacts of the project.

The steps required to obtain approval for both federal and non-federal development have often been labeled as burdensome and unnecessary. For non-federal developers, however, the costs of collecting and providing environmental information is typically less than one percent of overall project costs, and has not been a major deterrent to development. Costs of mitigating environmental impacts at particularly sensitive sites can range from 5 to 10 percent of the total construction costs, but are often much less. In fact, as a result of skyrocketing energy prices and federal financial incentives, interest and activity in all forms of hydropower have increased.

Most important, projects that only five years ago were considered hopelessly uneconomic are now feasible candidates for development, as evidenced by the current interest in microhydropower (capacity less than 1 MW) and in the renovation of turn-of-the-century facilities.

The recent efforts by FERC to streamline licensing for non-federal hydropower developers were initiated as a result of the Public Utility Regulatory Policies Act (PURPA) and the Energy Security Act. Those acts and FERC's implementing regulations were constructed to safeguard environmental protection while at the same time moving closer to the nation's goal of energy self-sufficiency. These actions, however, assisted only small-scale, often baseload, operations projects. No steps have been taken to speed the federal process or to otherwise assist in the development of large new projects.

In summary, recent federal legislation and the escalating price of oil have favored the development of small-scale hydroelectric resources, primarily at existing dams. As reflected by the growing number of applications for preliminary permits from FERC, not only is substantial development likely, but also the environmental consequences are expected to be minor. However, because small dams cannot satisfy requirements for firm power, their near-term contribution to total U.S. hydroelectric generation is expected to be low. In addition, hydropower can be added at many federal water projects. With the rapidly rising cost of energy, retrofitting dams with hydroelectric generating capacity is now considered profitable. In light of their shorter planning and approval times, non-federal developers may provide the quickest way to start producing power at these sites.

Mitigation and Cumulative Impacts

The Fish and Wildlife Coordination Act seeks ". . . to provide that wildlife conservation . . . receive equal consideration and be coordinated with other features of water-resource development programs . . ." The Act states further that "justifiable means and measures" to prevent loss and damage of wildlife resources "as well as providing for the development and improvement" of fish and wildlife should be included in project plans.

The Federal Power Act specifies that hydropower plants should be adapted to a ". . .comprehensive plan for the development of the river basin. . ." This implies that the cumulative impact of hydropower development on a river's flow regime, riverine fishery, and other resources in the river basin will be evaluated.

Institutional and technical measures to meet the intent of both of these laws are lacking. The development and implementation of successful mitigation techniques lag behind hydropower technology. Furthermore, mitigation is often not attempted until years after the dam is constructed.

Techniques for assessing the cumulative impacts of many projects in a river system are still in the early developmental state. Relatively simple impact indices are a promising tool for future hydropower planning at the river-basin level. In the meantime, projects are independently reviewed and almost universally approved without consideration of the cumulative impacts on the river basin.

Alteration of downstream flow is a predominant and severe cumulative impact of extensive hydropower development in a river basin. Methodologies to assess instream flow requirements are still under development, but those that are available either require extensive data gathering or are not universally applicable. Agencies in New England are leading the way, having adopted an instream flow policy for hydropower projects--a policy that uses a standardized method for determining "aquatic base flows." Water laws in the western United States, however, limit the implementation of minimum streamflow standards. When standards are included as project conditions, they are frequently violated.

Despite strong legislation, present hydropower impacts on fish and wildlife resources have been only partially lessened. Although extremely expensive, technical engineering measures such as fish ladders and hatcheries are more frequently adopted than institutional measures such as the acquisition of land for wildlife habitat and minimum flow standards for aquatic life. Wildlife losses are generally greater than fish losses, because fewer technical measures are available for their protection.

Findings

There are several findings that emerged from the environmental assessment.

1. THERE ARE NO OVERRIDING ENVIRONMENTAL IMPACTS THAT SHOULD CATEGORICALLY LIMIT FUTURE HYDROPOWER DEVELOPMENT, ALTHOUGH AN ENVIRONMENTAL ASSESSMENT, AND, IF NEEDED, AN ENVIRONMENTAL IMPACT STATEMENT MUST BE CONDUCTED PRIOR TO DEVELOPMENT.

All hydropower facilities create environmental impacts; some more than others. However, there exists techniques or procedures to ameliorate impacts or to modify projects to meet environmental standards. There may be cases where hydropower development would result in unacceptable impacts, however, many sites could be developed with proper environmental safeguards. The environmental assessment/EIS process should be used to insure adequate protection of environmental resources.

2. MITIGATION MEASURES TO PREVENT OR REDUCE THE ENVIRONMENTAL IMPACTS OF HYDROPOWER PROJECTS ARE LIMITED BY TECHNICAL KNOWLEDGE AND INSTITUTIONAL ARRANGEMENTS. MEASURES TAKEN TO CORRECT THESE LIMITATIONS COULD BENEFIT HYDROPOWER DEVELOPMENT.

Technical solutions to some environmental problems are unavailable or untested. Methodologies to quantitatively predict, evaluate and compensate for impacts are not available. For example, there is no generally accepted means to predict the impact on fish of flow changes downstream from a reservoir. At best, interim techniques are being used. Compounding this lack of knowledge and methods become ineffective planning process to incorporate mitigation measures.

3. IF FURTHER MAJOR HYDROPOWER DEVELOPMENT IS TO PROCEED, PLANNED DEVELOPMENT AND IMPLEMENTATION OF MITIGATION MEASURES MUST BE CONSIDERED FROM THE STANDPOINT OF THE ENTIRE RIVER BASIN, RATHER THAN BY EACH INDIVIDUAL SITE.

Widespread development of hydropower within a river basin, both through the retrofitting of existing dams and the development of new sites, can cause widespread and costly impacts to the ecosystem. Many impacts, particularly those that involve fish and wildlife, are cumulative and cause eventual impacts to the basin that are more severe than the sum of the impacts of each individual project. Basinwide planning has proven effective in evaluating tradeoffs between energy alternatives and environmental consequences. Moreover, it can provide the basis for proposing and implementing systemwide measures to mitigate adverse impacts. The Pacific Northwest Power Planning and Conservation Act has established a regional council to accomplish just that. In addition, Bonneville Power Administration has been granted broad authority to provide for the future power needs in the region and to work with the council to protect and enhance the fish and wildlife resources of the region. The Tennessee Valley Authority and other regional agencies have made important progress in systemwide energy and environmental planning. Whether an existing regional agency (such as a river basin commission), or a new one created especially for that purpose, is given the responsibility, the following objectives should be accomplished:

- Ensure the development of an integrated energy supply system designed to meet the region's future electrical demand.

- Protect environmental quality, particularly those resources that are especially valuable to the residents of the region.

- Coordinate hydropower development and operation within the basin to optimize the value of the energy produced for the regional system.

Planning at the river-basin level should ensure that hydropower is developed in the manner most appropriate to the needs and desires of the population within the region.

CHAPTER 1

INTRODUCTION

A. Purpose

This report presents an environmental assessment of future development of hydropower in the United States. The environmental assessment was prepared as part of the National Hydroelectric Power Resources Study (NHS). Congress authorized the Corps of Engineers to conduct the NHS to evaluate the potential for additional hydropower development and to prepare a plan for future studies of feasible sites. The environmental assessment examines the environmental impacts associated with hydropower development in general and potential environmental consequences of developing sites identified by the NHS. The environmental assessment also proposes measures to deal with expected environmental impacts. This report can serve as a starting point for future environmental studies of hydropower projects.

B. Objectives

The objectives of the environmental assessment were:

- to identify the generic environmental impacts of hydropower projects.

- to evaluate the potential environmental impacts by region based on NHS estimates of future development.

- to assess the effectiveness of environmental legislation and planning procedures associated with hydropower development.

- to identify actions which could mitigate expected environmental impacts associated with future hydropower development.

C. Approach

Six separate tasks were undertaken to complete the environmental assessment and accomplish the objectives of the study. The tasks were:

- examine hydropower technology to identify potential environmental impact.
- classify conventional hydropower facilities to differentiate potential for environmental impact.
- identify generic environmental impacts of different classes of hydropower projects.
- evaluate potential for regional environmental impacts that would result from developing feasible sites identified in the NHS regional reports.
- assess environmental legislation and planning.
- assess any special environmental problems identified during the study.

Under the first task the individual components that comprise a hydropower project were examined to determine how each component might contribute to environmental impacts. Dams, spillways, intake and related structures, turbines, and generators were included. Also, components that are used to mitigate the impacts of hydropower projects, such as fish ladders, were examined in this task.

All conventional hydropower facilities were classified into separate categories depending on whether the site was at an existing dam or at an undeveloped site, the type of operation, and the size of the site. The rationale for this classification was to differentiate potential sites by characteristics that could be used to show distinctions in likely environmental impacts. The classification scheme was used in the regional environmental assessment.

The third task required the identification and description of generic environmental impacts. An environmental impact matrix was developed under this task to catalogue all possible impacts. Using the matrix and the hydropower classification scheme, the classes of projects with most potential for environmental impacts were highlighted.

The NHS regional reports identified a set of potential sites across the nation that are considered most suitable for further study. The regional environmental assessment examined the characteristics of these sites and the potential consequences of developing these potential sites. The assessment is an overview of the regional environmental problems that would be likely if the sites were developed. For each region the sites are examined in groups. No individual site analysis was performed.

Under task 5, the study examined current planning procedures used in developing hydropower sites. Current environmental legislation was also analyzed.

Finally, the last task examined two special environmental problems associated with hydropower development: mitigation of environmental impacts and the problem of cumulative impacts of a set of hydropower facilities.

D. Report Organization

This report consists of an executive summary, 7 chapters and appendices. The executive summary presents the major findings of the study. Chapter 1 is the introduction to the report. Chapter 2 discusses elements of hydropower technology that relate to the environmental impact of hydropower. Also hydropower projects are classified by type of operation, site status, and size to illustrate environmental differences. The generic environmental impacts of hydropower projects are described in Chapter 3. Chapter 4 develops regional environmental profiles in preparation for a regional assessment. Chapter 5 contains the regional environmental assessment of developing the potential sites identified as part of the NHS. Chapter 6 describes the major pieces of environmental legislation that affect hydropower development and the environmental planning measures that are required of developers. Mitigation of environmental impacts and the subject of cumulative impacts of a system of hydropower projects are discussed in Chapter 7.

CHAPTER 2

HYDROPOWER TECHNOLOGY

The environmental impacts of any given hydropower development depend on the characteristics of the site and the design of the facility. The impact of the 5,000 MW Grand Coulee Dam in eastern Washington is much different from that of a 2 MW retrofit project at an existing dam in upstate New York. Yet, individual characteristics of all potential sites and projects could not be considered in a national assessment. Instead, such an assessment must consider categories of hydropower configurations and regional distinctions in environmental impact characteristics. This chapter describes the configurations and the rationale for a site classification system. The regions and the rationale for selecting regional boundaries are described in Chapter 4.

A. Technology Overview

Hydropower technology is relatively simple and well-developed. Facilities vary in design and layout, but all projects consist of a dam or diversion structure to impound or control water and create a hydrostatic head, a turbine to convert water flow to mechanical energy, and a generator to convert the mechanical energy to electricity.

1. Dams

The type of dam associated with a hydroelectric facility is primarily determined by the physical conditions of the project site. The topographical and geological characteristics of an area often dictate the type of dam that can safely be constructed. Other considerations include the availability of building materials and project costs.

Dams are classified by structural design and materials of construction. The major structural categories are gravity, arch, buttress, and earthfill.

Plan and section views of these four categories are shown in Figure 2.1. The first three categories are commonly constructed with concrete, and the last, with earth and rock materials. A gravity dam depends on its own weight for stability. Arch dams transmit most of the horizontal thrust of the water behind them to the abutments, and therefore have thinner sections than comparable gravity dams. Arch dams can be used only in narrow canyons where the canyon walls are capable of withstanding the thrust forces. The buttress dam consists of sloping flat slabs supported at intervals by buttresses. Earthfill dams are embankments of rock or earth with an impermeable core to control seepage (Linsley and Franzini, 1971).

Earthfill dams are more prevalent where rivers tend to be rather wide with gradually sloping banks. Narrow rivers with steep walls are often better suited to one of several concrete dam structures. The choice of concrete or earthfill material, however, is not an indication of scale. Both large and small dams can be created from either material. The size of a dam is partially a function of mode of operation. Run-of-river facilities typically have dams less than 65 feet high, whereas storage reservoirs used for peak power production have dam heights of more than 65 feet.

Plan profile schematics of a storage hydroelectric operation are shown in Figures 2.2 and 2.3. Run-of-river schematics are shown in Figures 2.4 and 2.5.

Dams of all types cause many environmental impacts; usually more than any other single feature of a hydroelectric development. The degree of environmental change a dam induces is related to its size and operational type. Large dams designed for peaking operation cause more changes in the natural environment than smaller, run-of-river dams. Environmental effects of dams are discussed in Chapter 3.

2. Spillways

Spillways are reservoir controls used to discharge excess water around, through, or over the crest of the dam without damage to the structure. They

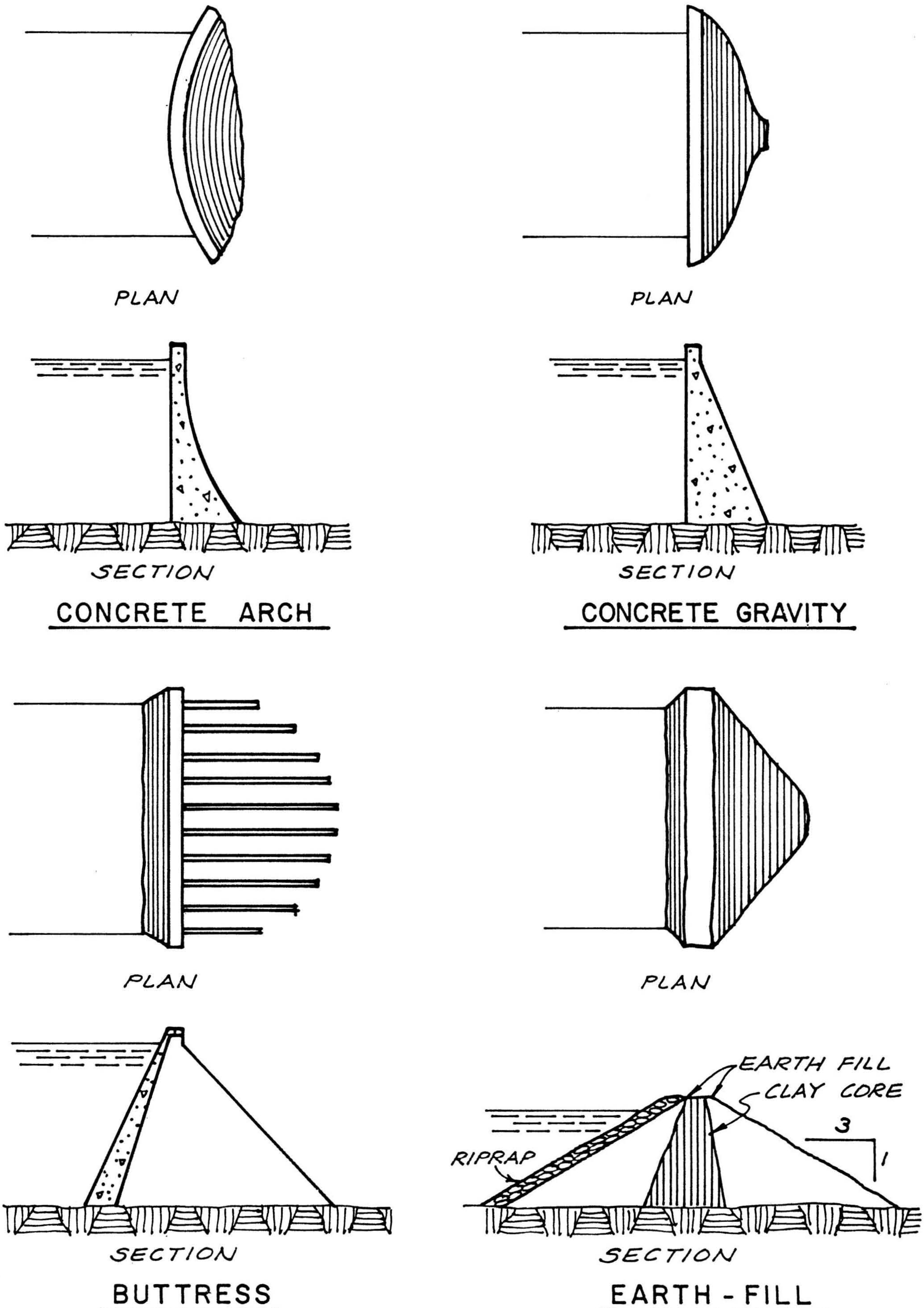


Figure 2.1 MAJOR TYPES OF DAMS

Source: U.S. Fish and Wildlife Service, 1977

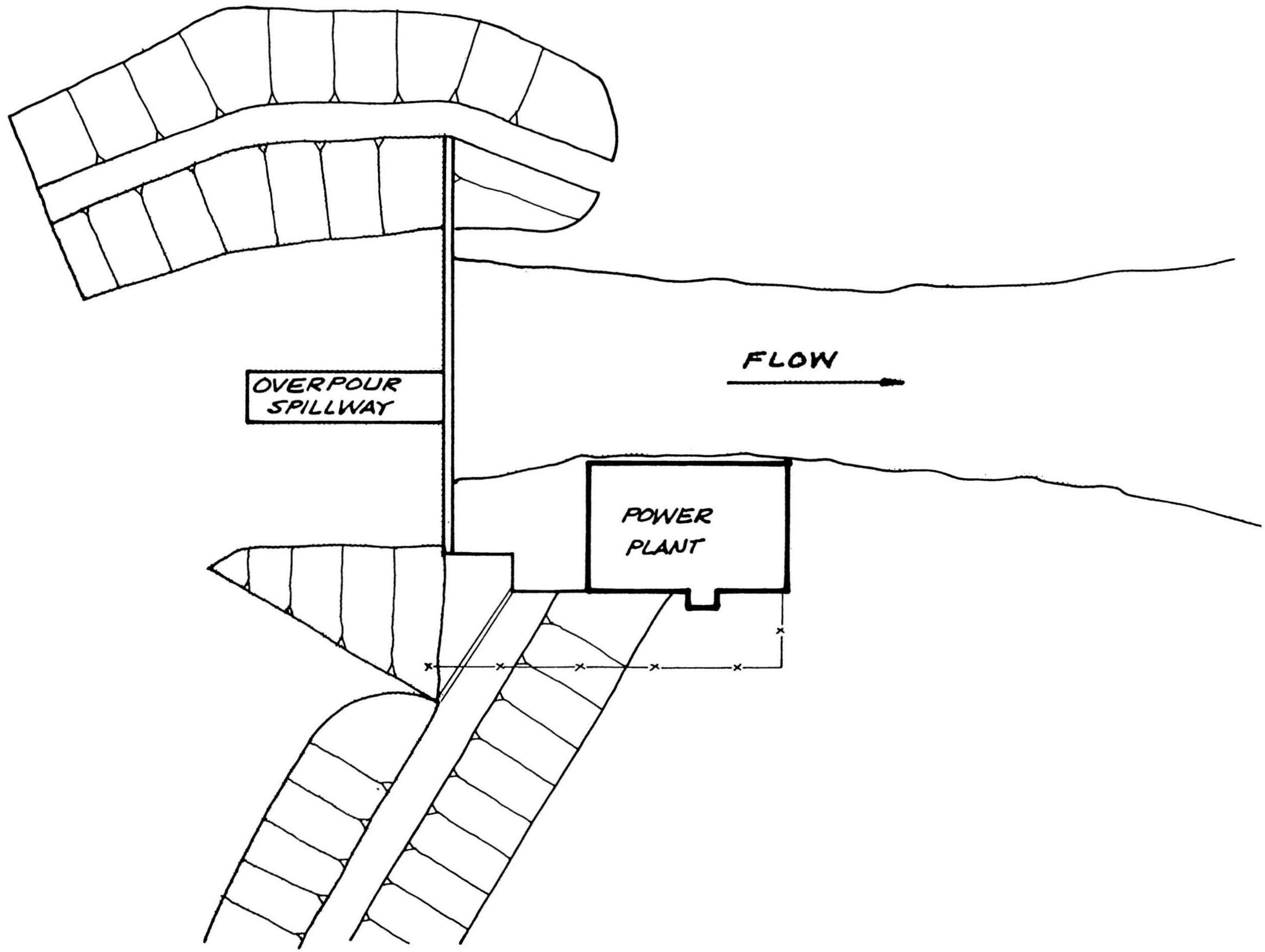


Figure 2.2 STORAGE HYDROELECTRIC OPERATION – PLAN VIEW

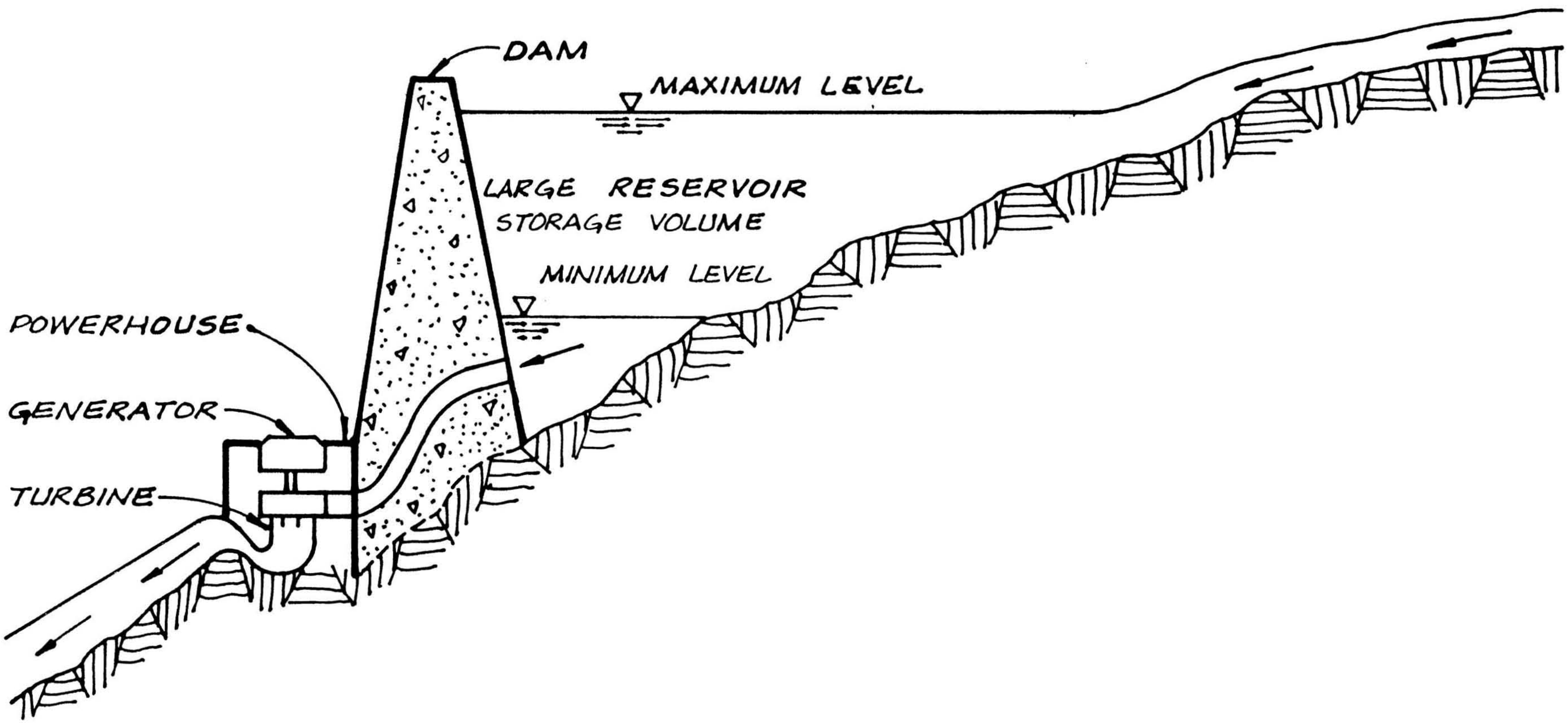


Figure 2.3 TYPICAL STORAGE HYDROELECTRIC PROJECT – PROFILE VIEW
Source: Federal Power Commission, 1976.

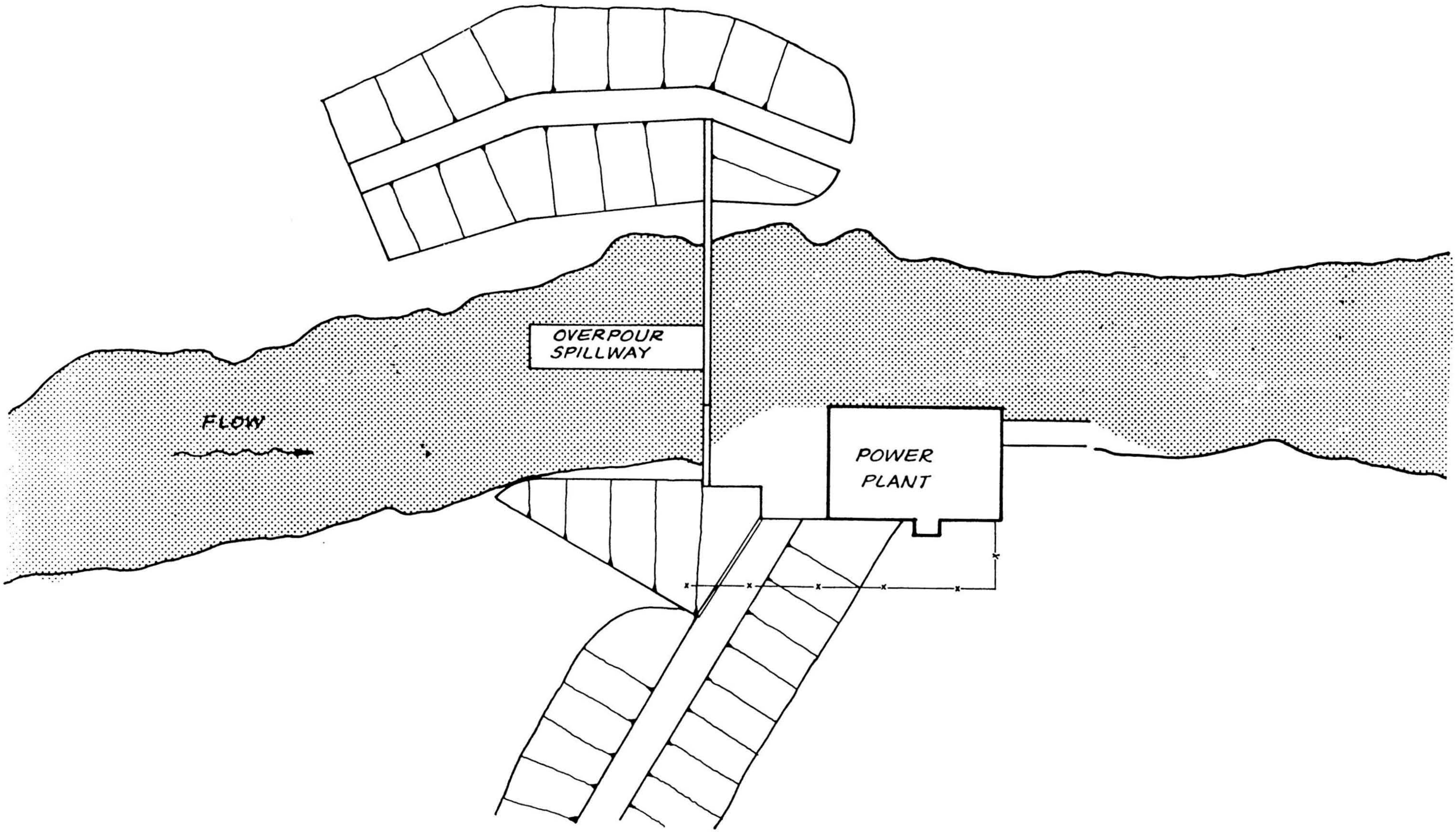


Figure 2.4 RUN-OF-RIVER HYDROELECTRIC OPERATION – PLAN VIEW

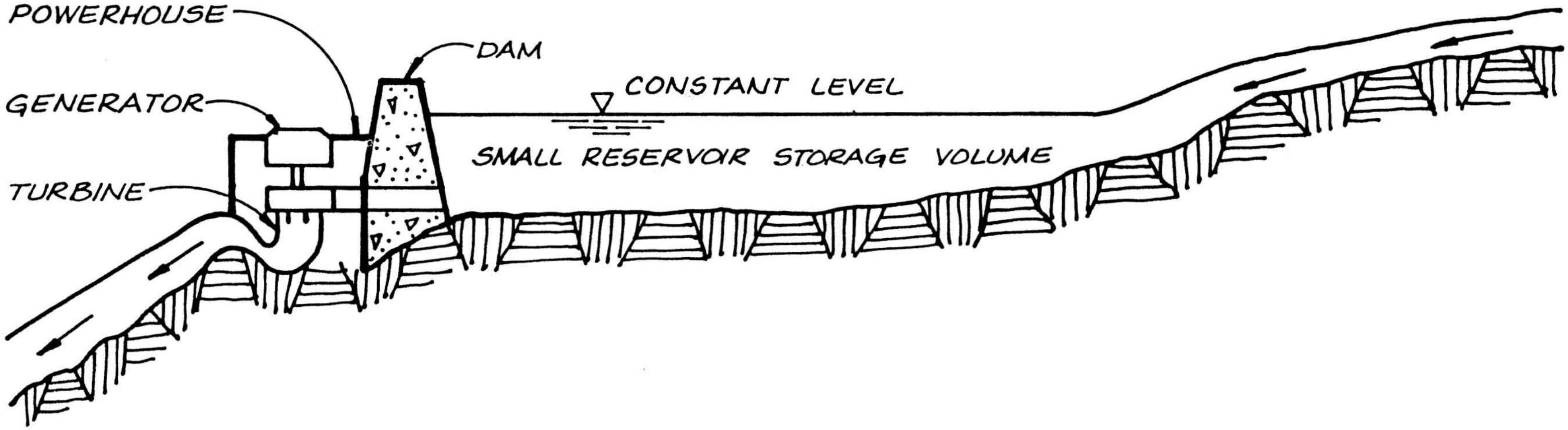


Figure 2.5 TYPICAL RUN-OF-RIVER HYDROELECTRIC PROJECT – PROFILE VIEW

Source: Federal Power Commission, 1976.

are a feature of all hydroelectric facilities. The major types of spillways include overflows, chutes, side channels, and shafts.

Overflow spillways employ a portion of the dam crest as an area for water to flow over. Earthfill dams cannot safely pass water over their crests; therefore, either a concrete weir section is added to the earthfill dam to serve as a spillway, or one of the other spillway designs is chosen.

Chute spillways consist of steeply sloping, lined, open channel adjacent to the dam. They commonly accompany earthfill dams to carry water away from the dam and prevent overtopping.

A side channel spillway is often used in narrow canyons where the crest length is insufficient to permit an overflow or chute spillway. Water is first passed over a weir and into a channel that runs parallel to the dam crest, and then eventually discharged downstream.

The shaft (or "morning glory") spillway is a vertical funnel with its top as the lip of the spillway. It connects to an outlet conduit that passes either around or through the dam (U.S. Fish and Wildlife Service, 1977).

The environmental impacts associated with spillways, exclusive of the dam, are relatively few. Certain designs can contribute to atmospheric supersaturation of spilled waters.

3. Intakes and Related Structures

Intakes are structures that control water flow into the penstock and conduits, which lead to the turbines. Intakes are usually designated by the term low-pressure or high-pressure. The difference between the two is a function of the depth of the intake in relation to reservoir water levels. High-pressure intakes are situated at lower levels, and are characterized by a greater water flow velocity. Low-pressure intakes are nearer the surface.

Withdrawal depth (high or low) can impact the downstream environment by causing changes in water temperature and sedimentation. To reduce these effects at some projects, multi-level intakes are used to control the quality of water withdrawn from the reservoir (U.S. Fish and Wildlife Service, 1977).

4. Turbines

Hydropower turbines can be divided into two basic categories: impulse and reaction. Each is suitable for a specific range of hydraulic head.

The impulse turbine uses the energy available from head and flow in the form of a jet (or jets) of water impinging on "buckets" attached to the periphery of the runner. The general design of an impulse turbine is shown in Figure 2.6. The impulse turbine was perfected by Pelton, and is often identified as a "Pelton Wheel" in the literature. Impulse turbines are usually used when heads exceed 1,000 feet.

The reaction turbine, on the other hand, captures the potential energy of head and flow by forcing the water over or through a series of blades (the runner), which use the changes in water pressure, velocity, and momentum to a mechanical advantage. Different types of runners have been developed to satisfy different operating conditions. The propeller runner is used for heads of less than about 120 feet. When the flow through the turbine is fairly constant, the blades are fixed; when the flow varies, the blades can be made moveable so that the angle they present to the water can be optimized. The latter type of turbine is often called a Kaplan runner, after its designer. For heads between the range of the propeller and impulse turbine, the usual choice is the Francis turbine (or runner), also named after its designer. These turbines are illustrated in Figure 2.7. The main difference between the propeller and Francis runner is that the latter has more blades set at a steeper angle to the water. Other differences that separate the Francis from the propeller runners result from the hydraulics involved with smaller water passages. Therefore, even though both types of runners operate on the reaction principle, the propeller and Francis runners are completely different in appearance.

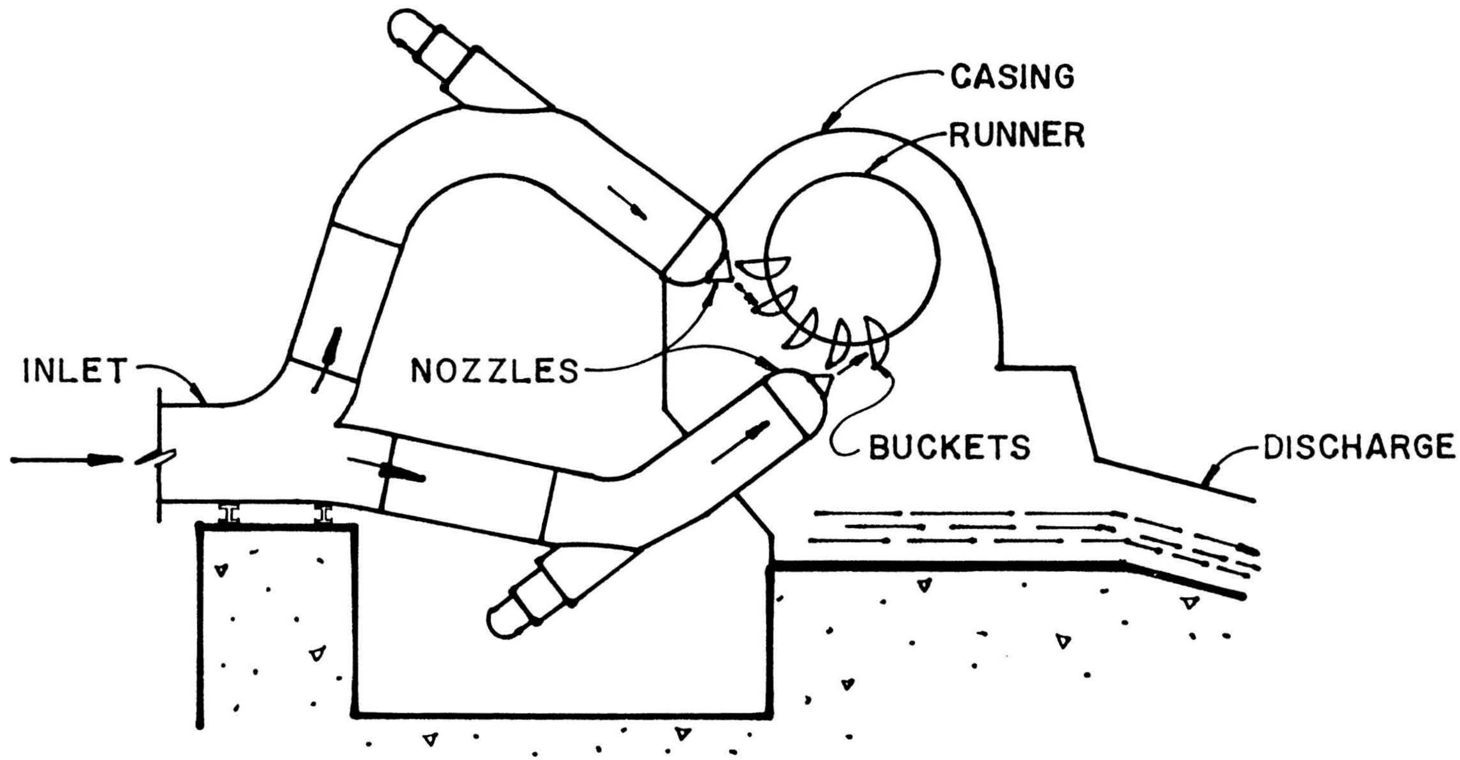
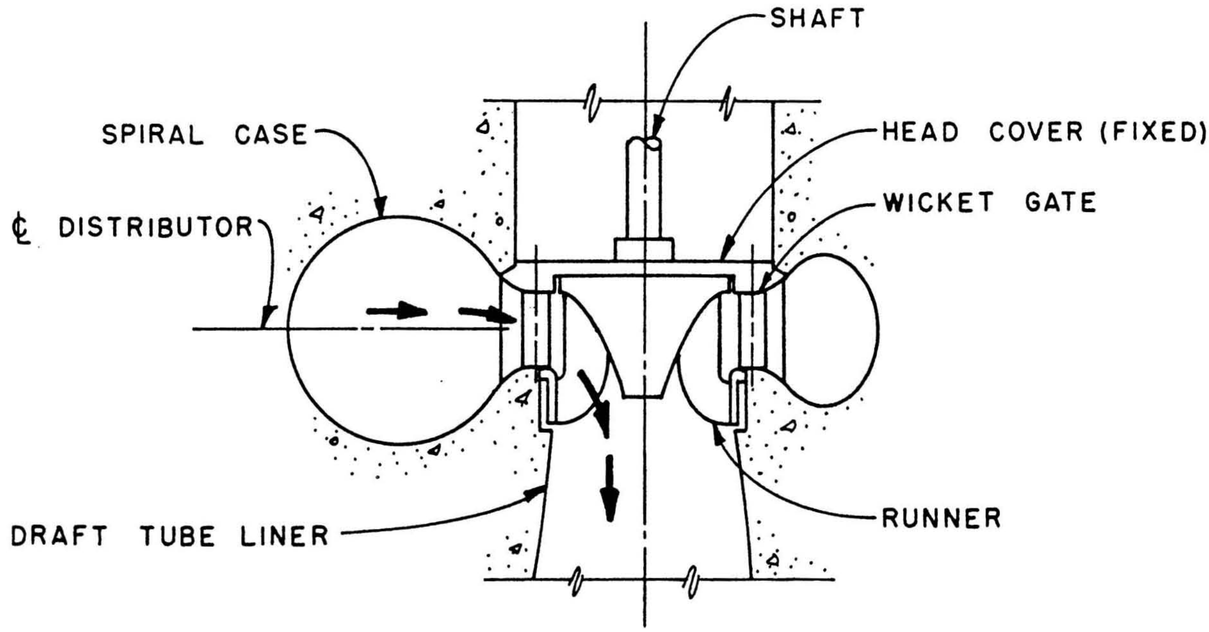
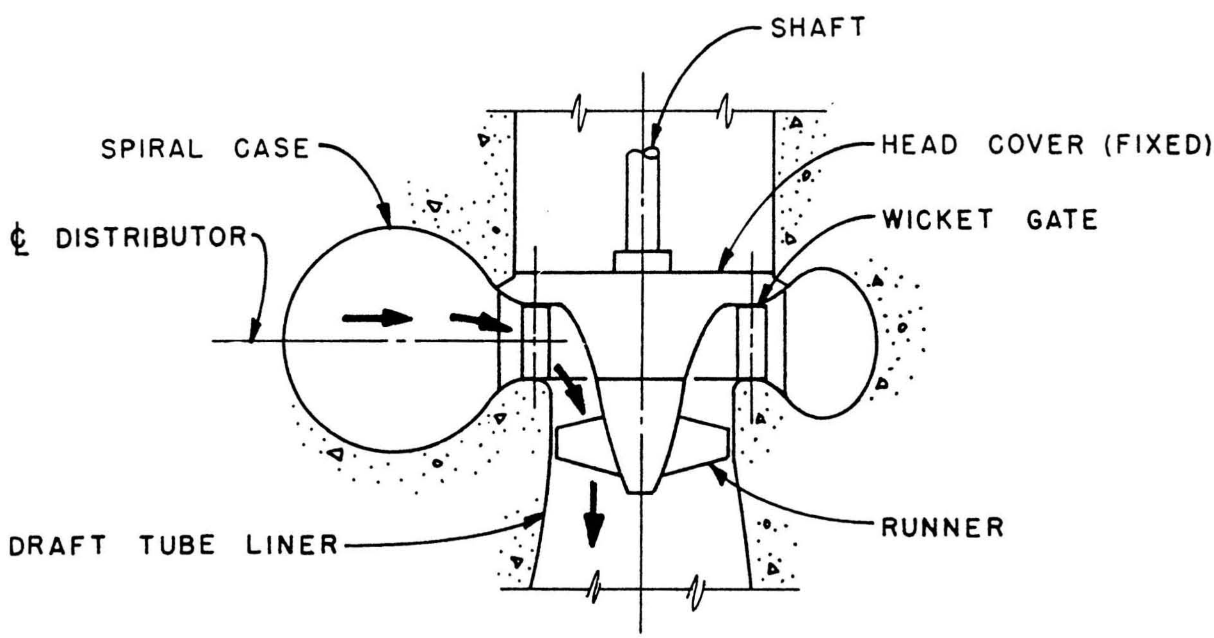


Figure 2.6 IMPULSE TURBINE



FRANCIS TURBINE



PROPELLER / KAPLAN TURBINE

Figure 2.7 SCHEMATIC DIAGRAMS OF FRANCIS AND PROPELLER/KAPLAN TURBINES

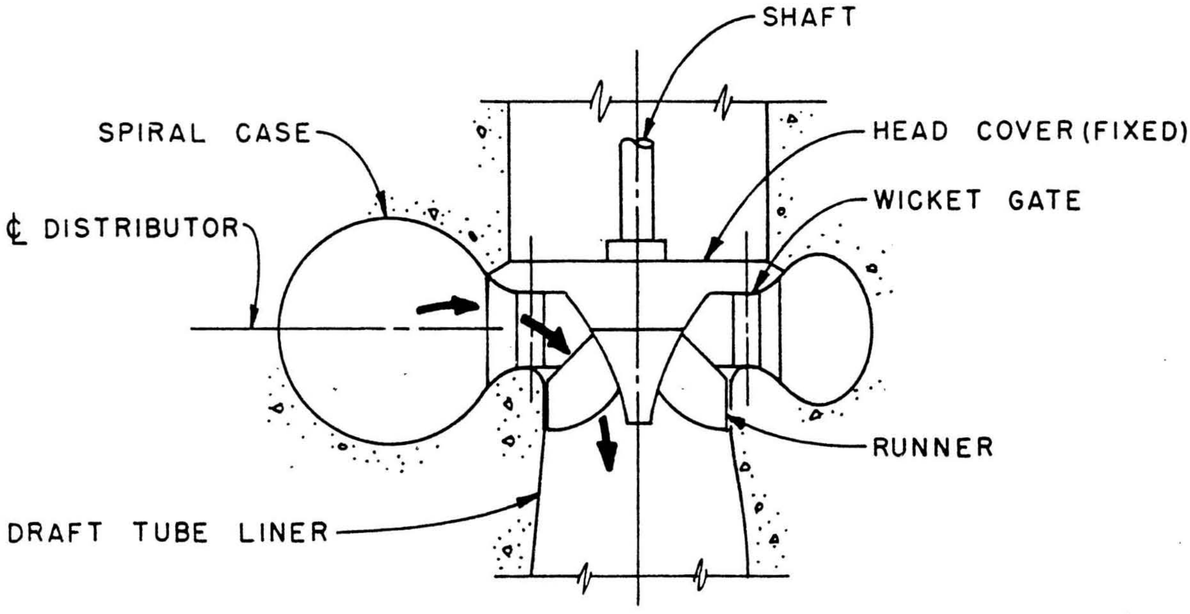
The cross-flow and mixed-flow turbines offer additional variations on the basic impulse and reaction types of turbines. Both are shown in Figure 2.8. The mixed-flow turbine is a reaction turbine that is somewhat of a cross between the Francis and propeller turbines. The mixed-flow turbine is designed to function most efficiently in the transitional head range between Francis and propeller runners -- from 50 to 200 feet.

The cross-flow turbines are really a hybrid turbine arrangement. They can be operated over an extreme head range -- from 10 to 600 feet. At design heads of 150 feet or greater, the cross-flow runner is operated as an impulse turbine. At lower heads, it functions like a reaction turbine. The cross-flow turbine, while having the potential to be used with many head levels, operates most efficiently in the head range of 200 to 300 feet.

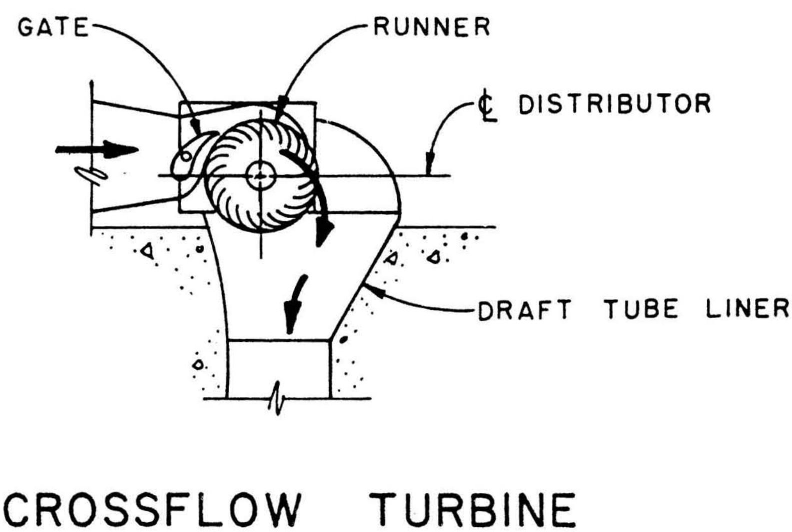
Two newer designs are classified as tube turbines (an Allis-Chalmers trademark) and bulb turbines. The tube turbine is a propeller unit that provides the highest possible operating speed and the greatest possible capacity for a given size. It is horizontally arranged and allows great flexibility in locating the powerhouse and ancillary equipment. Its space requirement is only two-thirds that of a conventional vertical turbine for the same net head and turbine output (Allis-Chalmers, 1980).

The bulb unit is hydraulically the same as other propeller turbines, but, unlike other arrangements, has the generator directly coupled with the turbine, encased in watertight steel housing, and submerged in the water stream. Like the tube turbine, the combined bulb unit is oriented horizontally (Chapus and Haddad, 1978).

Hydropower turbines do cause environmental impacts. Fish can be killed if they pass through the turbine. Some designs and mitigation measures are effective in reducing fish mortality, but a certain amount is inevitable.



MIXEDFLOW TURBINE



CROSSFLOW TURBINE

Figure 2.8 SCHEMATIC DIAGRAM OF MIXED AND CROSS-FLOW TURBINES

5. Powerhouse

The powerhouse of a hydroelectric facility houses the hydraulic and electrical equipment against the elements. It is usually constructed of reinforced concrete, and can be any of three basic designs -- outdoor, semi-enclosed and fully enclosed. Outdoor powerhouses are uncovered, to allow maintenance to be performed by a mobile crane unit. Semi-enclosed structures are covered, but have a hatch that opens to allow maintenance. Fully enclosed structures house all mechanical and electrical equipment, and provide a permanently mounted indoor crane.

Within the powerhouse, hydraulic structures are designed to take in water at low velocities, accelerate the flow through the turbine, and then slow it down for discharge into the tailrace. The internal structures can be open flumes, or concrete or metal spiral casings.

Open flumes are generally used in low-head, small-capacity facilities. Concrete spiral-type are generally used for heads of up to 90 feet. Metal spiral casings are usually associated with heads above 90 feet (Linsley and Franzini, 1972).

The environmental impacts of the powerhouse structure are minimal, although short-term disturbances can be expected during construction.

6. Generators

Another component of a hydropower facility is the electrical generating equipment. The two basic types, synchronous and induction, are used in combination with all types of turbines and operating procedures. The major difference between the two is that shychronous generators have a frequency control and induction generators do not, and thus can only be used with large electric distribution systems. There are no environmental impacts caused by generating equipment.

B. Mitigation Technology

A growing awareness of hydropower's environmental impacts has resulted in the development of a number of mitigation techniques. These mitigation techniques are designed to prevent or lessen the negative environmental effects of a hydroelectric facility. Some of these techniques are engineering solutions, and involve the addition of specific physical components to the design of a hydropower plan. Following is a discussion of the major technological components being used as mitigation measures.

1. Fishways

Fishways to allow upstream fish passage around dams employ one of two basic principles. Fish ladders provide a flow of water, over a series of pools, that allow fish to swim and jump upstream under their own power. Other fishways mechanically lift fish, as though they were riding an elevator, or alternately fill and release water in a series of locks similar to navigation locks, floating the fish up to higher levels in the stream.

Conventional fishways are classified as weir-types, orifices, denil types, and vertical slot baffles. Weir-type passages consist of a series of rising pools created by walls or baffles that control water levels. They are often designated as fish ladders, and their physical characteristics do give the impression of ladder rungs (Figures 2.9 and 2.10). Orifice fishways have submerged openings through a series of baffles, rather than the upper surface openings of the weir-type (Figure 2.11). Denil fishways utilize a series of blades and vanes to slow the waterflow and allow the fish to swim through. Vertical slot baffles are walls with shapes and openings designed to partially turn the flow upstream and dissipate energy (U.S. Fish and Wildlife Service, 1977).

Although the type, size, and overall design of a fish ladder depends on the species of fish and the characteristics of the site and the project, some generalizations on their design are possible. The slope of a ladder is

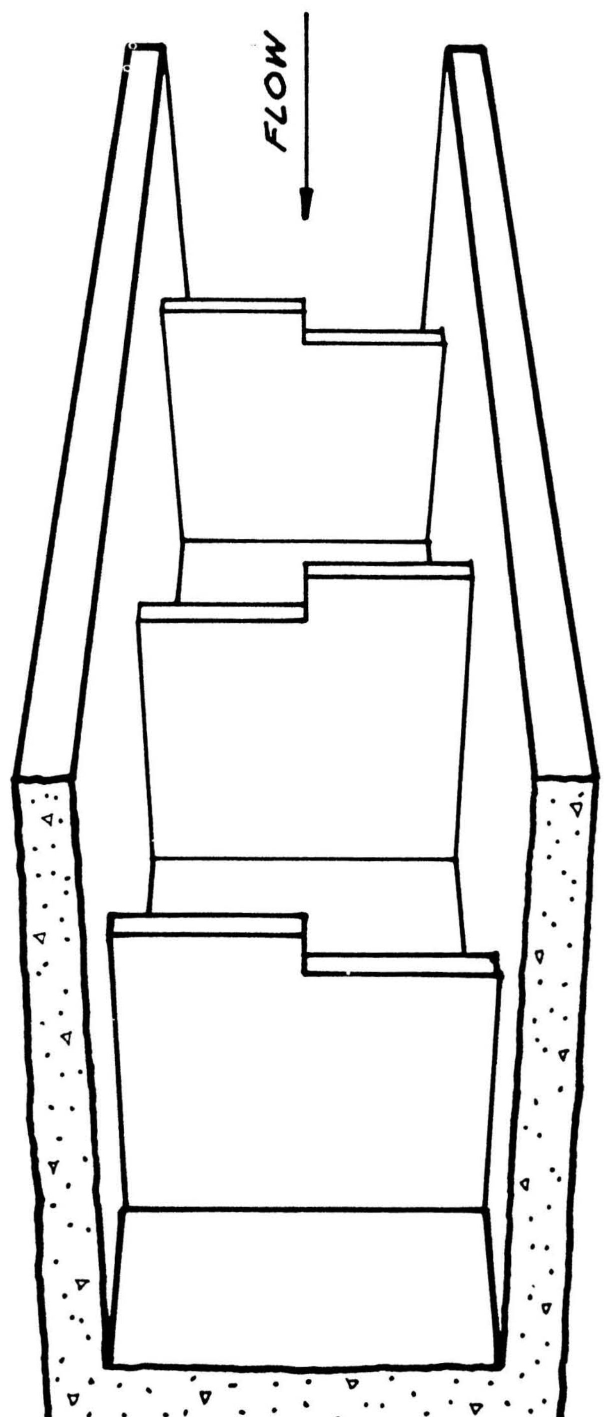


Figure 2.9 TYPICAL WEIR FISHWAY – FRONT VIEW
Source: U.S. Fish and Wildlife Service, 1961.

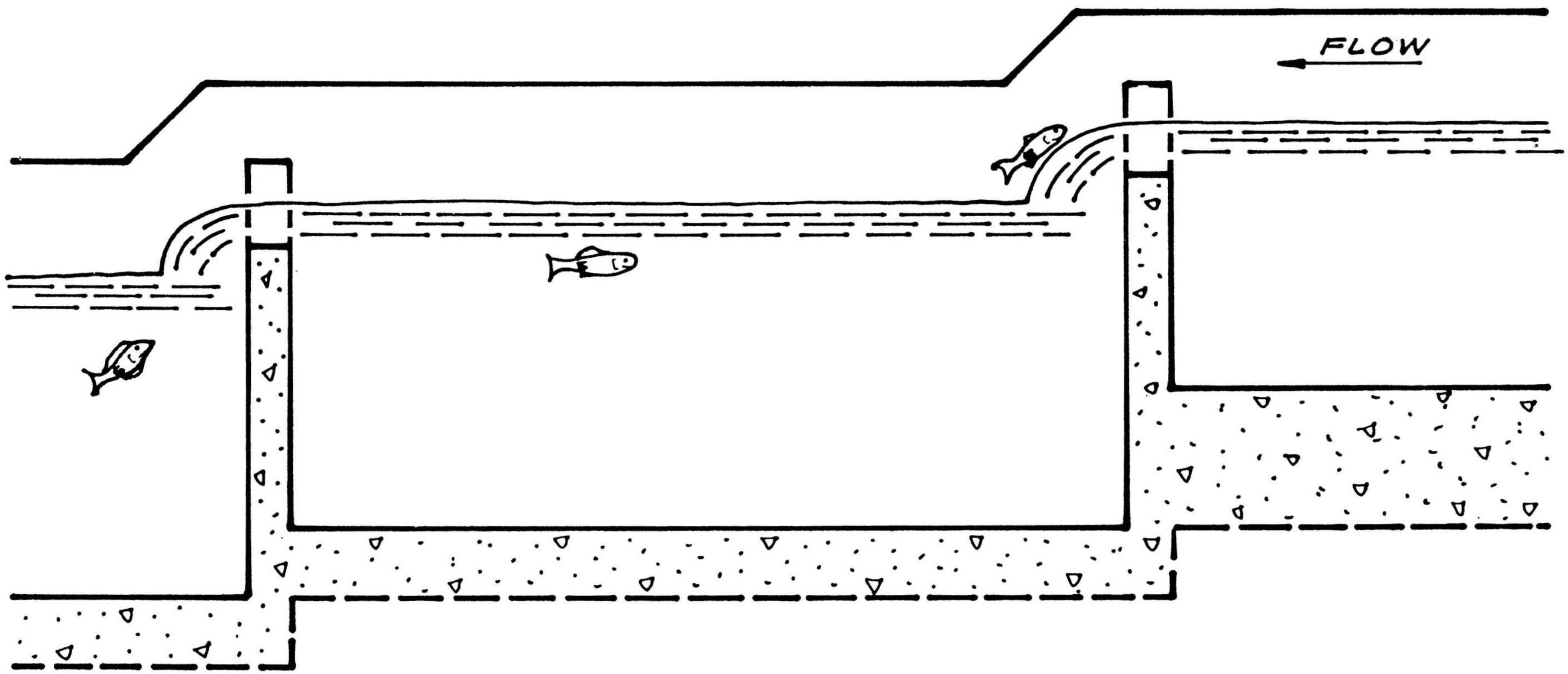


Figure 2.10 WEIR FISHWAY – SIDE VIEW

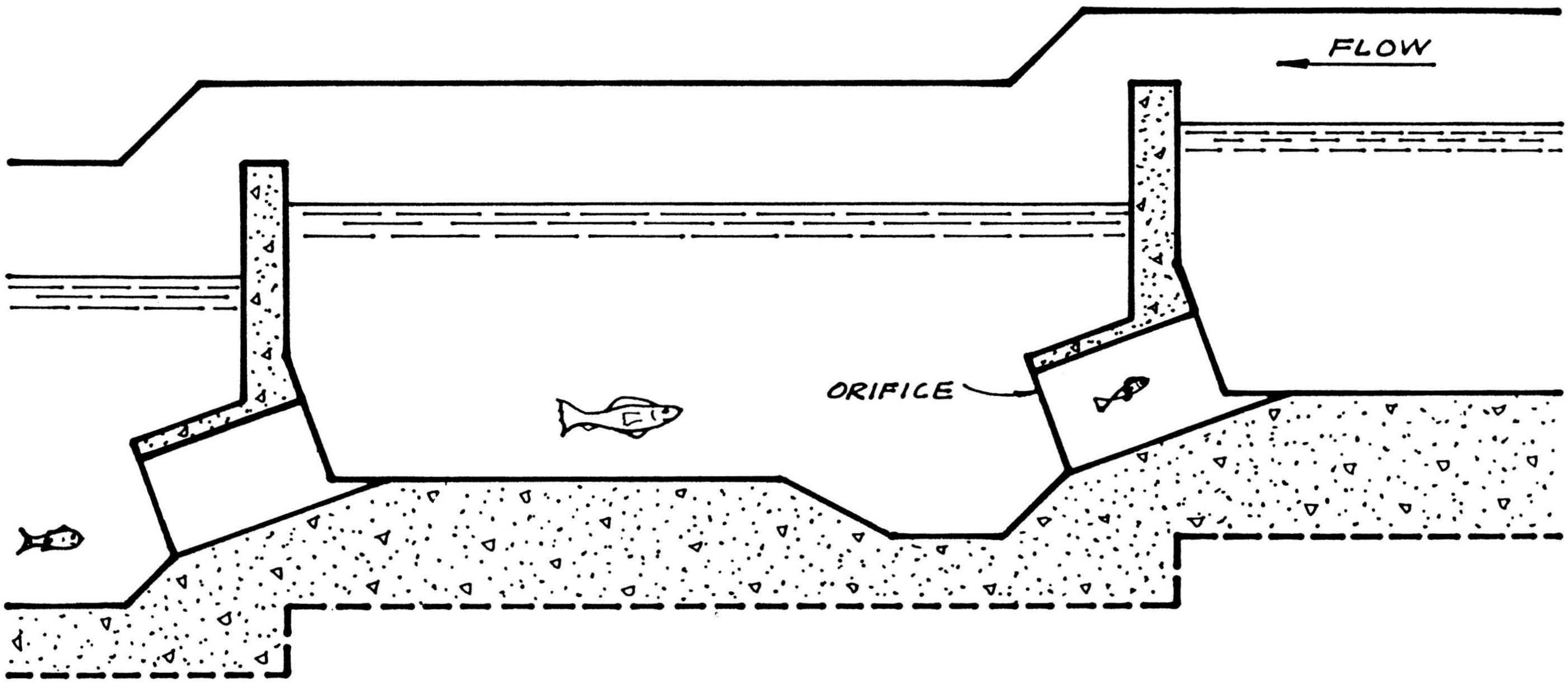


Figure 2.11 SUBMERGED ORIFICE FISHWAY – SIDE VIEW
Source: U.S. Fish and Wildlife Service, 1961

usually about 10 to 15 percent, with drops less than 12 inches, and pool lengths from 8 to 20 feet. The need for careful design, loss of hydropower production, and high costs are limitations common to all fish ladders. (See Nelson et al., 1978a; Bell, 1973; and Clay, 1961 for a discussion of the advantages and limitations of each design.)

The effectiveness of a fish ladder is highly sensitive to proper design elements. It is not uncommon for fish ladders to be totally ineffective because of insufficient attraction flow or some other design problem. Some curtailment in fish passage can be expected, however, even with a properly designed fish ladder. Although fish ladders have been effectively used at large reservoirs in the Pacific Northwest, ladders are generally most successful at low-head dams (less than 100 feet high).

Fish ladders directly conflict with hydropower generation in two ways. First, attraction flows over the ladder cannot be used to generate electricity; Bell and Hildebrand (1979) estimate that fish ladders at small-scale hydropower plants require approximately 3 percent of the streamflow. Second, fluctuating reservoir levels for hydropower peaking require that fish ladder design compensate for varying flows.

Fish ladders are expensive, both relative to total project costs and relative to the number of migrating fish at the site. Bell and Hildebrand (1979) estimate that fish ladders for a small-scale plant cost between $6,000 and $8,000 per vertical foot in capital expenditures and about $200 per vertical foot annually for operation and maintenance. Costs are significantly higher for large-scale facilities. The two ladders at the 100-foot high, 600-MW Ice Harbor plant at the Snake River in Southeastern Washington cost $10 million (Nelson et al., 1978a). Although the number of returning Chinook salmon and steelhead trout passing Ice Harbor dam varied considerably from 1962 to 1979, the average between those years was about 117,200 annually (Ebel, 1979).

More complicated fish passage systems included fishlocks and fish elevators. Fishlocks are not widely used in the United States, but are often found in Europe. They consist of two types -- surface locks and pressure locks. Both move fish by filling a chamber, into which fish have been attracted, up to the reservoir level and then releasing them. Surface locks are open to the atmosphere; pressure locks are not (U.S. Fish and Wildlife, 1977).

Fish elevators are any mechanical means for transporting fish around a dam. A typical elevator system uses a short fish ladder to attract fish to a holding pond where fish are crowded into a hopper that lifts the fish to the top of the dam. The fish can then be released in the reservoir or transported by truck to be released at other locations upstream. Elevators are most often used with very high dams where conventional passages may be inadequate (U.S. Fish and Wildlife, 1977). Although this technique is generally very successful, it is also very costly. Injury to fish from handling is another drawback of this technique (Nelson et al., 1978a).

2. Diversion Screens

A variety of screens and other bypass systems have been developed to divert fish migrating downstream from turbine intakes. Theoretically, a range of factors, including light, velocity, channel shapes, depth, sound, odor, temperature, bubbles, electric fields, and visible curtains (such as chains), can be used to guide fish; however, wire screens are the most common and most effective means of diverting fish (Bell, 1973).

Fish screens physically prevent fish from entering turbine intakes and direct fish through a channel that leads to the river below the dam. Obviously, the size of the fish to be screened determines the appropriate mesh. Head loss and velocity of approach must be minimized to prevent injuring fish. Accumulation of debris, particularly algae, is a problem with fish screens. Various designs use wiper blades, jets of water, and brushes to prevent clogging (Bell, 1973).

If properly maintained, fish screens and turbine bypass systems can be highly successful. Nelson et al., (1978a) reports that approximately 80 percent of the downstream migrating fish entering a turbine intake can be diverted with traveling screens and a bypass system.

3. Water Quality

Two water-quality parameters that can be affected by hydropower development, and for which some type of engineering mitigation is possible, are temperature and dissolved oxygen levels. Temperature stratification can occur in a reservoir. If all releases through the turbine come from one stratum, downstream water temperature can be affected. A method that can help adjust stream temperature involves using multi-level turbine intakes so that water is released from several levels of the reservoir. Low-level intakes have successfully been used to provide a coldwater fishery habitat downstream.

Water released from a stratified reservoir can also drastically alter the dissolved oxygen level of the downstream water. A lack of sufficient oxygen is detrimental to both the fish and plant life and can result in changes in species number and composition. Sufficient oxygen is necessary for the stream to stay environmentally balanced and support aquatic life.

Techniques to increase dissolved oxygen levels include aeration systems, often aerohydraulic guns placed low in the water, to force oxygenation. A new refinement recently reported by TVA concerns the use of "hub" baffles welded at an angle above a small air vent, around which water flows through the turbine. Results show that this new device raises the downstream oxygen level by 100 percent, with only a one percent decrease in generating efficiency (Engineering News Record, 1980).

Another device used to maintain water quality is a spillway deflector, designed to reduce nitrogen supersaturation (Figure 2.12). As discharged water flows over a spillway and plunges into a deep basin, air becomes entrained in the flow, causing large amounts of nitrogen to be dissolved in the water. The excess nitrogen is especially lethal to trout and salmon. Deflectors built near the base of the spillway redirect the water flow and

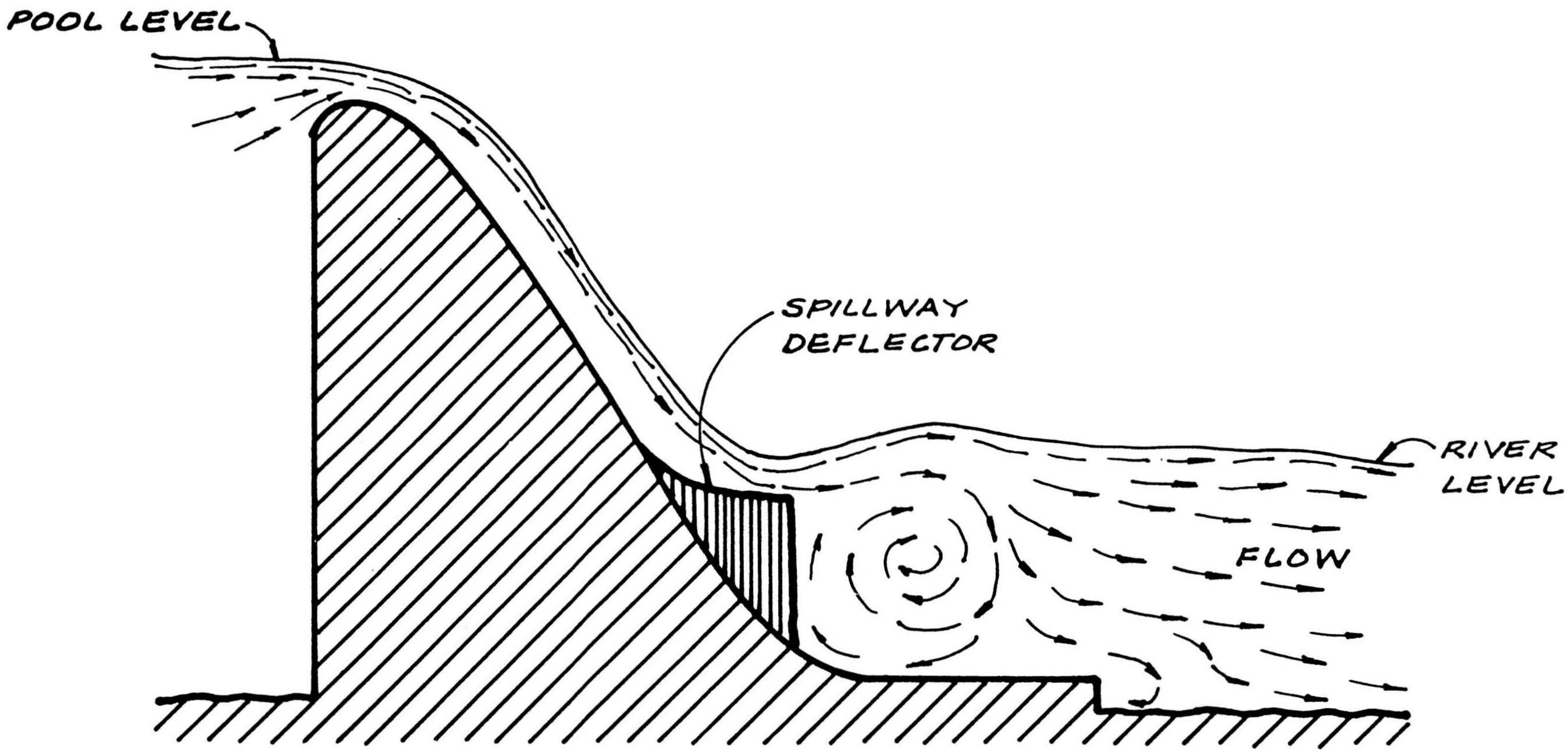


Figure 2.12 OVERFLOW SPILLWAY

Source: U.S. Fish and Wildlife Service, 1977.

keep it from plunging too rapidly and too deeply. They have been installed at dams on the Columbia and Snake Rivers and have resulted in lowered nitrogen levels for all except extreme flows, thus decreasing fish mortality from supersaturation (Nelson et al., 1978).

C. Classification of Hydropower Configurations

One task of this study was the development of a hydropower classification system. Many characteristics of a hydropower project could be used to classify all types of facilities; the primary concern, however, was to adopt a system that could accurately describe the engineering aspects, while illustrating important environmental differences. In addition, the classification system must be concise to allow the environmental consequences to be summarized in matrix form.

To satisfy these criteria and develop the classification system, past studies were reviewed. The starting point was the Corps of Engineer's National Hydropower Study Form 1 classification, which classified hydropower sites by their status and type of operation. Six categories of both status and operation were used, providing 36 separate categories (see Figure 2.13). Such a number of categories, however, was considered redundant for a matrix of environmental impacts, and unnecessary to show key differences among hydropower facilities.

To identify a more concise classification system, three alternative classification systems were formulated and evaluated (Figure 2.14). The evaluation served to: (1) ascertain the most sensitive impacts, (2) see if environmental impact profiles could typify a region and be used as a guide to selecting representative case studies, and (3) ascertain which environmental categories (e.g., hydrology, aquatic biology, etc.) would recur and be useful in developing an environmental impact matrix or other display.

Appendix B documents the evaluation procedure. The results suggest that environmental impacts indeed recur and can be related to certain characteristics of hydroelectric facilities.

Status of Waterway Structure	TYPE OF OPERATION					
	Run-of-River	Diversion	Reservoir	Reservoir with Diversion	Irrigation Canal	Pumped Storage
Existing						
Existing with Power						
Existing with Retired Power Plant						
Breached						
Breached with Retired Power Plant						
Undeveloped						

Figure 2.13 HYDROPOWER CLASSIFICATION SYSTEM USED BY THE U.S. ARMY CORPS OF ENGINEERS

HYDROPOWER CONFIGURATIONS

DEFINITION #1

	RUN OF RIVER				PEAKING			
	Existing		Undevel.		Existing		Undevel.	
Head (meters)	< 20	> 20	< 20	> 20	< 20	> 20	< 20	> 20

DEFINITION #2

	RES.+RES.W/DIV				DIV.		R OF R	
	Existing		Undevel.		Existing		Undevel.	
Capacity (MW)	< 25	> 25	< 25	> 25	< 25	> 25	< 25	> 25

DEFINITION #3

	UNDEVEL.			EXIST. W/POW EXIST.WO/POW		
Capacity (MW)	< 15	15-25	> 25	< 15	15-25	> 25

Notes: RES = reservoir
DIV = diversion
Undevel = undeveloped site
R of R = run-of-river

Figure 2.14 ALTERNATIVE HYDROPOWER CLASSIFICATION SYSTEMS

From the comparison of the alternative methods for classifying hydropower, projects, the evaluation concluded that two modes of operation -- storage or run-of-river -- and two sites status identifiers -- existing or undeveloped -- are most important to determine the environmental effects of hydropower projects and therefore should be used in the classification system.

Mode of operation is an important distinction. Run-of-river hydropower plants do not alter existing downstream flow patterns of a river. Electricity is generated as the water is available. On the other hand, storage hydropower plants store water until electricity is needed. Large flows are released when generating; small flows when not.

Run-of-river plants require less impoundment for hydropower generation whereas storage projects, which are usually designed to meet peaking power demands, require larger impoundments. Run-of-river plants lack the magnitude of impacts associated with frequent fluctuations in water level. Storage facilities often have rapid and extreme fluctuations in water level, together with abrupt cycles in the passage and restriction of water flow, creating water circulation patterns that are significantly different from downstream and reservoir conditions at run-of-river plants. The environmental impacts associated with these two distinct operational modes are discussed in detail in the following chapter.

The number and kind of impacts associated with undeveloped versus existing sites are of major significance. In general, existing structures have many of the auxillary facilities, such as access roads, transmission lines, and dam structures, already in place. Retrofitting required only the addition of turbines and their associated facilities, with their associated impacts on fisheries. Development at undeveloped sites, on the other hand, causes land inundation, streamflow alteration and other impacts which have additional effects beyond the retrofitting of existing power plants.

The classification system includes an additional category to denote the special case of constructing power facilities on a man-made canals or other diversions. From an environmental perspective, conduits can be viewed as potentially negative features, because they can create barriers to wildlife movement, particularly for large animals, and may be significant visual intrusions in the project areas. However, because canals are already an artificial environment, the impacts they cause are significantly different from impacts caused by impoundments on a natural stream.

Appendix B also includes the analysis for defining ranges of project size. Several factors influenced the choice of this parameter. Three ranges were selected -- less than 5 MW, 5-30 MW, and greater than 30 MW. The number of sites capable of generating more than 100 MW are limited but because of their impact these sites are included separately in the regional assessment (Chapter 5).

Figure 2.15 summarizes the results of the derivation of major categories for classifying hydropower from the categories used in the Corps inventory. The system accurately distinguishes major engineering and environmental differences among types of hydropower, yet requires only six major categories, compared with the 36 categories in the Corps' classification system (Figure 2.16). Appendix C contains a more detailed description of the elements of each category as defined for the environmental assessment.

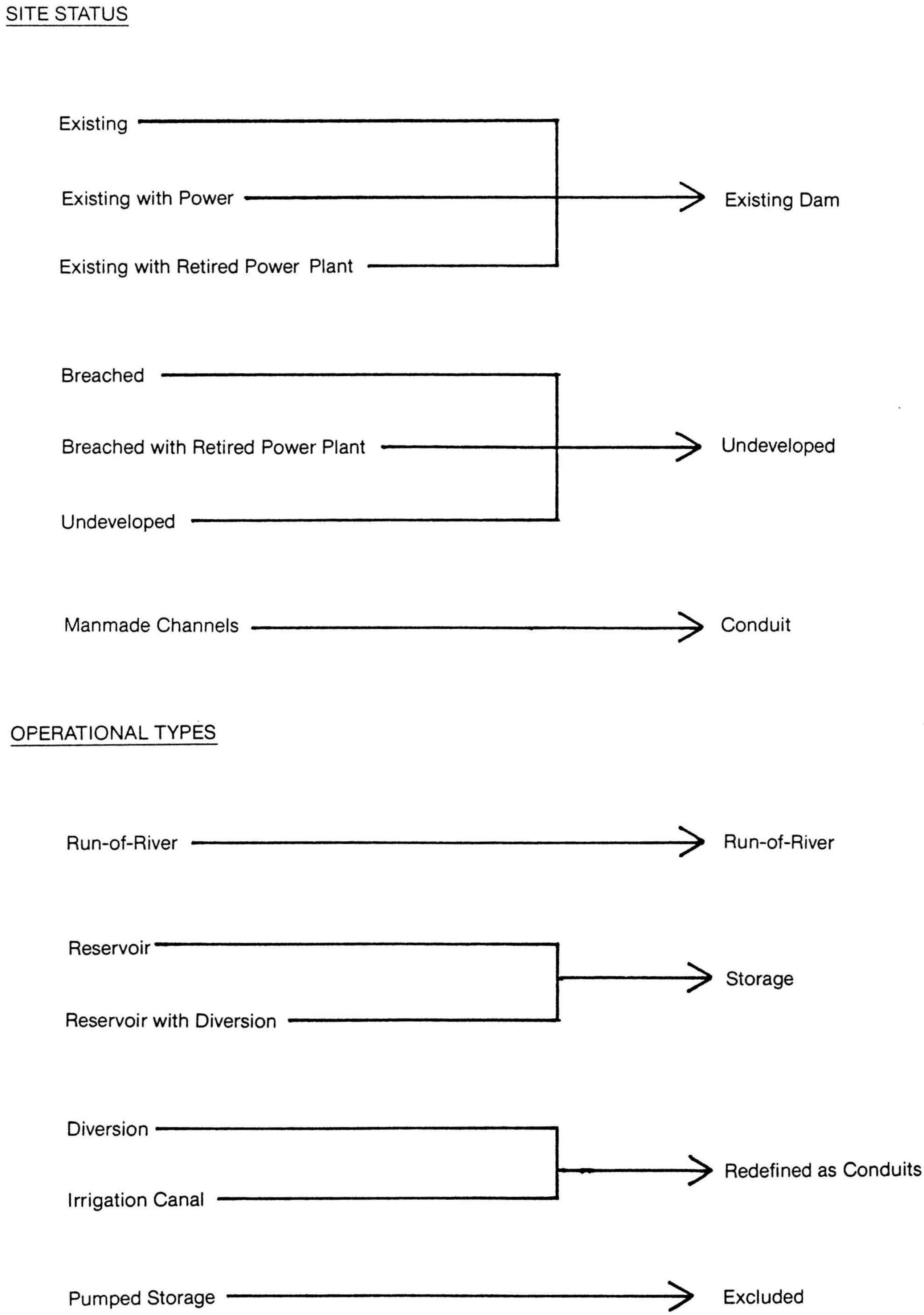


Figure 2.15 DERIVATION OF HYDROPOWER CLASSIFICATION CATEGORIES

<table>
<tr><td></td><td colspan="18">DEFINITION OF HYDROPOWER</td></tr>
<tr><td>TYPE OF OPERATION</td><td colspan="6">RUN-OF-RIVER</td><td colspan="6">STORAGE</td><td colspan="6">CONDUIT</td></tr>
<tr><td>SITE STATUS</td><td colspan="3">UNDEVELOPED</td><td colspan="3">EXISTING DAM OR CHANNEL</td><td colspan="3">UNDEVELOPED</td><td colspan="3">EXISTING DAM OR CHANNEL</td><td colspan="3">UNDEVELOPED</td><td colspan="3">EXISTING DAM OR CHANNEL</td></tr>
<tr><td>SCALE (MW)</td><td>< 5</td><td>5 – 30</td><td>> 30</td><td>> 5</td><td>5 – 30</td><td>> 30</td><td>< 5</td><td>5 – 30</td><td>> 30</td><td>< 5</td><td>5 – 30</td><td>> 30</td><td>< 5</td><td>5 – 30</td><td>> 30</td><td>< 5</td><td>5 – 30</td><td>> 30</td></tr>
</table>

Figure 2.16 HYDROPOWER CONFIGURATION CLASSIFICATION SYSTEM FOR ENVIRONMENTAL ASSESSMENT

CHAPTER 3

GENERIC ENVIRONMENTAL IMPACTS

Environmental effects of hydropower development vary with location and type of project. This first section of this chapter presents a framework for portraying the relationships between hydropower development and the resulting environmental effects employing a matrix that covers the full range of possibilities. The second section of this chapter summarizes the major issues and characteristics of hydropower development followed by conclusions about the generic environmental impacts of hydropower. For contrast, the last section describes the generic environmental effects of alternative sources of energy.

A. Relationships Between Hydropower Configuration and Environmental Impacts

The environmental impacts of hydropower development result from actions that change the physical, chemical, biological, or social condition of the area. The impacts, however, can often be mitigated. The two principal actions required for hydropower development are (1) construction, as in building a powerhouse, and (2) operation, as in raising the reservoir level by storing water. The changed environmental conditions are the resultant chemical, physical, biological, or cultural modifications to the environment. Known as primary impacts, they can be beneficial, adverse in the short term (lasting less than 2 years), or adverse in the long term (lasting more than 2 years). Deciding whether an impact is beneficial or adverse implies a value judgment.

Primary impacts result directly from a changed condition; secondary impacts, on the other hand, are social responses to the primary impact. Operational, institutional, legal, or other techniques, called mitigation measures, can reduce adverse primary and secondary impacts (see Chapter 7 for further discussion of mitigation). For example, as shown in Figure 3.1, a hydropower project at an existing dam with more than 30 MW of capacity operated as a peak power producer entails several new construction and operation actions, including surges of water released through the turbines, which change the condition of the environment by altering downstream flow. As one of the primary impacts of the newly changed condition, fish could be stranded in isolated pools as flows are abruptly reduced. As a secondary impact, recreational fishing would be lost or reduced. The impacts could be mitigated by regulating the rate at which flows are changed so that fish would be able to swim to the main river channel as secondary channels are dewatered.

A specific construction or operation action can generate several changed conditions, causing even more primary and secondary impacts. In Appendix F, all of the relationships among hydropower configurations, construction and operation actions, changed conditions, primary and secondary impacts, and mitigation measures are summarized in four environmental impact matrices. The matrices cover the four major environmental factors affected by hydropower

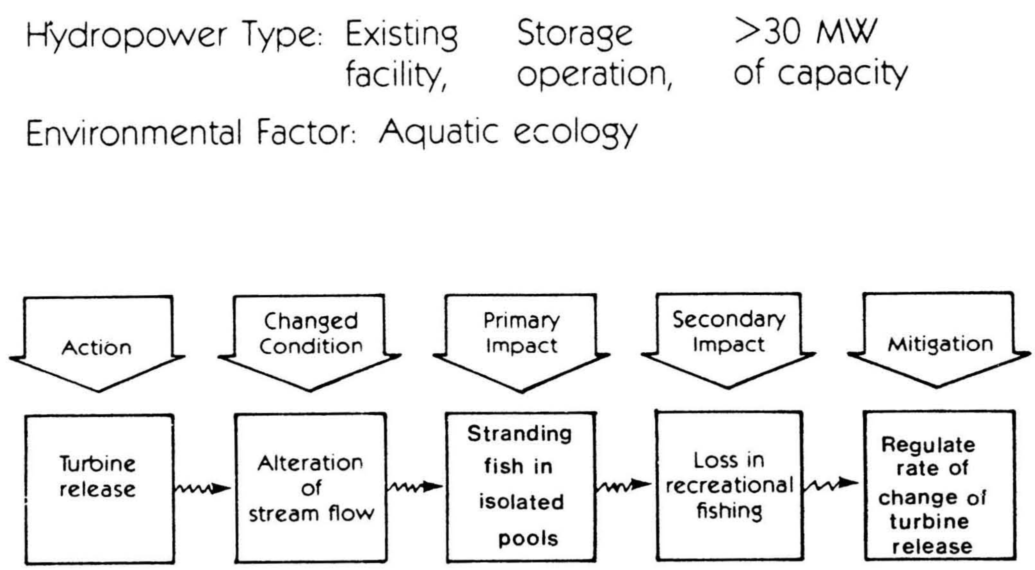


Figure 3.1 EXAMPLE OF CHAIN OF RELATIONSHIPS BETWEEN HYDROPOWER DEVELOPMENT AND ENVIRONMENTAL IMPACTS

development: water quality/use, aquatic ecology, terrestrial ecology, and land use and recreation. Each matrix defines the construction and operation actions associated with each hydropower configuration. The actions in turn, trigger 53 changed conditions in the environment that result in nearly 300 primary and secondary impacts. The matrices contain a concisely organized inventory of most of the possible generic impacts caused by hydropower construction in the United States. They represent generalizations extrapolated from case studies, personal interviews, and professional experience and are not intended to represent specific impacts at a particular site or region. Regional differences are analyzed in Chapters 4 and 5; the following section discusses the significant characteristics of hydropower development and its associated impacts.

B. Classification of Impacts

The environmental impacts of any hydropower project depend on the specific characteristics and design of the facility and the characteristics of the site. Some activities and resultant impacts can be expected from any type of hydropower project. Other types of impacts are associated only with undeveloped sites, or peaking operations, or conduits, or large-scale projects. As suggested in Figure 3.2, the significant impacts of hydropower development can be grouped into the four major categories just mentioned: undeveloped sites, peaking operations, conduits, and large-scale projects.

1. Impacts Common to All Types of Hydropower

The development of any hydropower project, regardless of its size, mode of operation, or status (existing or planned), connotes a range of actions and associated impacts. Installation of the powerhouse and transmission lines, for example, always results in short-term construction impacts and long-term displacement of natural features. Erosion, increased turbidity, noise, and dust are temporary impacts during line construction. Right-of-way clearing, however, can permanently destroy habitat for endangered or threatened species and other wildlife. Transmission lines and other new construction often

LARGE-SCALE

ACTIONS

- Switchyard Construction
- Relocation of Roads, Rail Lines, and Structures

IMPACTS

- Dam Safety Hazard
- Reservoir Stratification and Water Quality Problems
- Gas Supersaturation
- Delay in Fish Migration
- Potential for Flatwater Recreation, Flood Control, and Water Supply
- High Reservoir Evaporation Rates

PEAKING

ACTIONS

- Reservoir Storage and Release to Increase Value of Energy.

IMPACTS

- Daily, Seasonal Downstream Flow Alteration
  - Dewatering and Stranding Fish
  - Change in Riparian Vegetation
  - Flooding Waterfowl Habitat and Eliminating Nesting Islands
- Daily, Seasonal Reservoir Level Fluctuation
  - Visual and Recreational Nuisance of Exposed Drawdown Zone
  - Loss of Warmwater Spawning Grounds
  - Transport of Nutrients in Shallow Water to Deeper Water
  - Bank Erosion

CONDUIT

ACTIONS

- Stream Diversion

IMPACTS

- Dewatered Stream
- Disruption of Deer and Elk Migration

UNDEVELOPED

ACTIONS

- Dam Construction
- Reservoir Clearing

IMPACTS

- Change from River to Lake Environment
  - Loss of Riparian Edge
  - Change in Aquatic Plant and Fish Species
- Blocked Migratory Fish Runs and Loss of Spawning Grounds
- Trapped Nutrients and Sediment
- Altered Downstream Flow Regime
- Alteration of Water Temperatures
- Conversion of Land Uses
  - Loss of Wilderness and Whitewater Recreation
  - Loss of Wetlands
  - Loss of Agricultural Lands
  - Loss of Archaeological and Historic Sites

ALL HYDROPOWER

ACTIONS

- Excavation and Powerhouse Construction
- Transmission Line Right-of-Way Clearing and Line Construction
- Power Generation
- Maintenance, Including Dredging

IMPACTS

- Visual Intrusion Caused by Powerhouse and Transmission Lines
- Fish Mortality from Turbine Passage
- Potential Loss of Critical and Other Wildlife Habitat from Right-of-Way Clearing
- Increased Demand for Local Services from Construction and Maintenance Workforce
- Potential Release of Sediment and Toxic Substances
- Recreational Hazard

Figure 3.2 MAJOR CLASSES OF HYDROPOWER IMPACTS disrupt a scenic and biologically productive landscape, and are of major concern in the development of small-scale hydropower at existing dams in the West (U.S. Water and Power Resources Service, 1980). The construction of transmission lines can also open otherwise remote areas to increased hunting and fishing and result in the loss of wilderness. Construction of powerlines can disturb nesting areas and lead to a decline in bird populations, such as that of the sage grouse in the Missouri region. Transmission poles can serve as perches for raptors and increase their predation on animals in areas where natural perches are uncommon (DOE, 1979a). The use of herbicides to maintain rights-of-way can cause ecological impacts depending on the chemicals and extent of application.

Some level of fish mortality from turbine passage can be expected at any hydropower project. Fish mortality depends on the type of turbine, the head at the project, operational characteristics, and the type of fish. Studies in the Pacific Northwest have shown that some turbines can safely pass 85 percent of the salmon that enter the intakes (Bell, 1973).[1]

2. Impacts from Projects at Existing Dams

The installation of hydropower equipment at existing dams may conflict with historic sites, particularly in the Atlantic states. This is especially true for sites listed on or recommended for inclusion in the National Register of Historic Places (DOE, 1979b).

Dredging of sediment may be required to add hydropower facilities at existing dams. Disposal of sediment is controlled by Section 404 of the Clean Water Act administered by the Corps; if the sediment is toxic or hazardous, removal is controlled by the Resource Conservation and Recovery Act, administered by the U.S. Environmental Protection Agency. Although the environmental problems associated with dredging depend on many site-specific characteristics, dredging generally causes resuspension of bottom sediment,

---

[1] The cumulative impact on fish of turbine passage through a series of dams is discussed in Chapter 7.

low dissolved oxygen, high concentrations of nutrients and toxic contaminants, silt deposition below the dam, alteration of substrate, and associated changes in fish or other aquatic life (Loar et al., 1980).

3. Impacts from Projects at Previously Undeveloped Sites

The construction of a dam and reservoir-clearing inherent with hydropower projects at undeveloped sites introduce another range of potential environmental impacts. The primary ecological change is the transformation of a river environment into a reservoir environment. Depending on the size of the reservoir,, the flow of water through the reservoir, and other factors, the chemistry and biology of a reservoir can be completely different from that of the displaced river. Overhanging riparian vegetation generally keeps streams cooler than lakes. Impoundments lessen daily and seasonal temperature fluctuations downstream.

Other important processes in impoundments are the deposition of sediments, leading to the eventual filling in of reservoirs; the leaching of soluble materials; the creation of bottom mud deposits; and eutrophication. These physical and chemical changes result in substantial differences in the biota of impoundments as compared with the life in the streams they replace.

Creation of a new reservoir eliminates all of the land uses in the flooded area. Alluvial river channels typically provide valuable wildlife habitat and rich agricultural land; often the new shoreline, higher up on valley walls, is too steep and the soils too immature to support the wildlife cover and agricultural products that were displaced. Losses of cultural and recreational resources such as archaeological and historical sites, wilderness, and whitewater are also major issues frequently raised by reservoir construction.

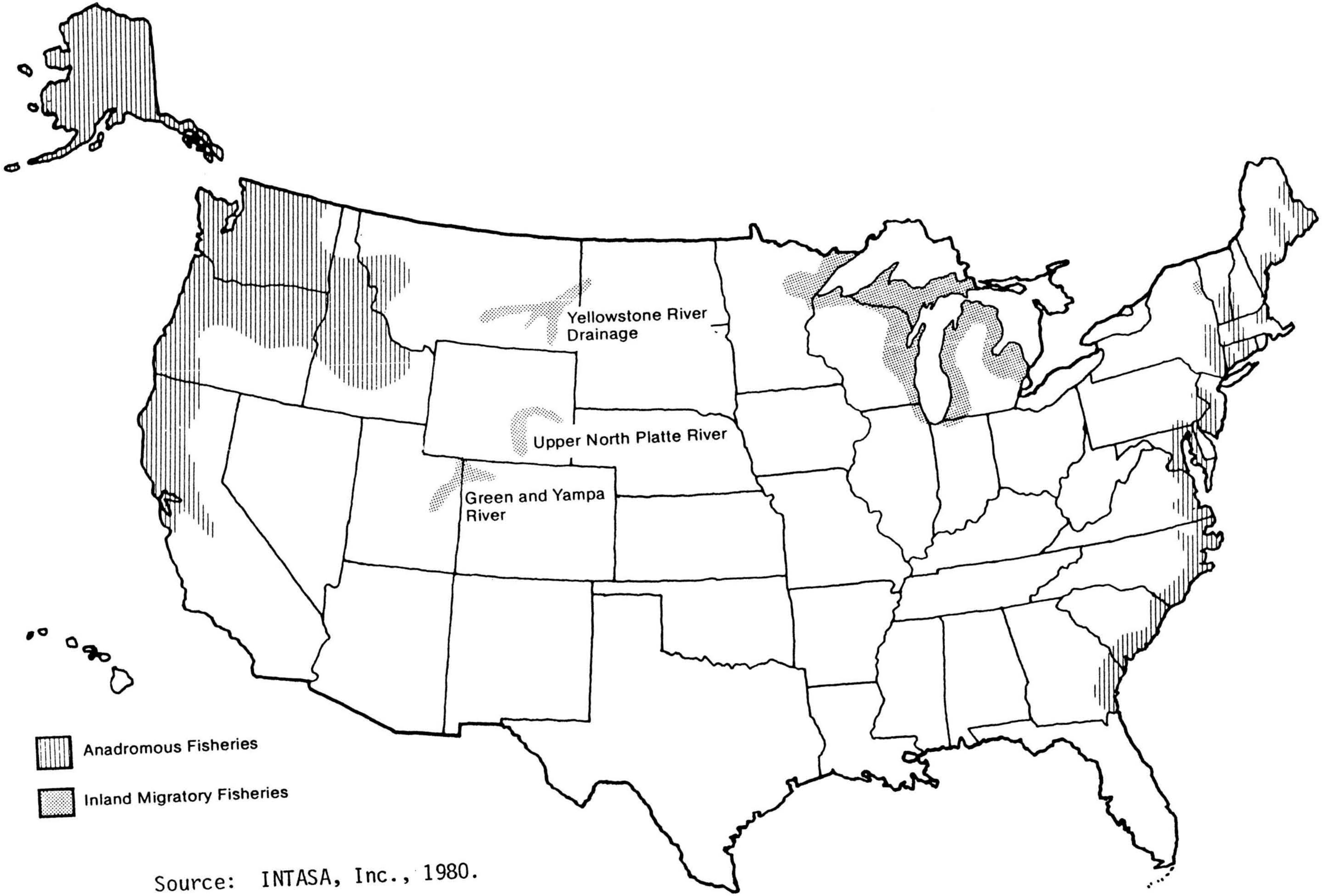
Unless fish passage facilities are provided, dam construction blocks the migration of anadromous and catadromous fish, and cuts off upstream spawning grounds. Even if passage is provided, temperature modifications and the lack of currents can disorient fish, retard migration, and generally increase disease and predation (Ebel, 1979). Riverine fish are replaced by lake fish that are better adapted to reservoir conditions (Holden, 1979). In addition, deep intake from poorly mixed reservoir waters can lower temperatures downstream from the dam and skew fish populations towards coldwater species. Figure 3.3 displays the areas in which anadromous and migratory fish are found and may be adversely affected by hydropower development.

Dams are extremely effective in trapping sediment transported by streams, decreasing the turbidity of downstream water (Ward and Stanford, 1979). Large reservoirs trap all but the finest particles of sediment (clay, primarily). Sediment accumulates along the bottom of the reservoir at varying rates, depending on the soil and erosion conditions in the watershed. Generally, the older a dam, the larger the amount of sediment trapped behind it. Sediment's property of carrying a negative charge that readily attracts and adsorbs certain chemical compounds to its surface may contribute to the problem of bioaccumulation related to pesticides and industrial chemicals in the Great Lakes region and other areas. In addition, anoxic conditions from thermal stratification can cause some pollutants to reenter solution, thereby becoming a greater hazard to aquatic species and to the public.

4. Impacts Caused by Peaking Operation

Operating a reservoir in a peaking mode, that is, controlling releases to match peak energy demands, creates another level of impacts within the reservoir and downstream of the dam. Reservoir fluctuations cause many biological impacts in addition to the aesthetic and recreational nuisance of the exposed drawdown zone.

Large seasonal or diurnal fluctuations in water level primarily affect the stability of the shoreline substrate and water quality. The effects have been summarized as (a) resuspension and redistribution of bed and bank sediment, (b) leaching of soluable matter from sediment from the bank as water moves out and the sediments become exposed to air, and (c) changes in sediment and



Source: INTASA, Inc., 1980.

Figure 3.3 ANADROMOUS AND INLAND MIGRATORY FISHERIES AND RESTORATION AREAS nutrient retention of the impoundment and changes in water quality as a consequence of altered circulation patterns and hydraulic efficiency (Szluha, 1979). These physical-chemical changes affect both aquatic and terrestrial biota by destroying habitat and shifting the type and number of species in the area.

In the beach zone, fluctuations in water level can decrease the water available for beach-zone vegetation and dry out aquatic plants exposed to the sun and wind. Consequently, life within the reservoir becomes less productive. Not only do aquatic marsh vegetation and semi-aquatic plants provide food for invertebrate fauna, which in turn provide food for fish, but they also protect the beach zone from sheet erosion and sedimentation and leaching of chemical compounds from the soil.

The shallow nearshore part of the reservoir (the littoral zone) is the most biologically productive and diverse portion of the reservoir. Throughout a large portion of their life cycles, most reservoir fish are closely associated with the littoral zone of a reservoir. Spawning, incubation, and the development of larval and juvenile resident fish all take place in shallow shore zones. Some warm water species required inundated brush and rocks for spawning. Fluctuation in water levels transports nutrient-rich water from the nearshore to deeper portions of the lake, out of the fertile zone where photosynthesis occurs, thus decreasing the food supply available to young fish. Fluctuations can also affect fish that inhabit the deeper portions of the reservoir by drawing off their food supply through the turbine intakes. Fluctuations in water level are major factors that affect optimal fish production and contribute to the instability of a reservoir's carrying capacity.

Sudden significant changes in downstream flow below the dam, resulting from hydropower peaking, can be detrimental to fish populations. Juvenile fish, newly emerged from gravel bottoms, tend to inhabit the quieter waters near river banks. During periods of high flow, sand bars are submerged, but a sudden decrease in flows can expose the bars and strand young fish before they can swim to deeper sections. If stranded, the young fish are vulnerable to predators and exposure.

Although aquatic species suffer the most direct impacts from hydropower peaking, fluctuations in streamflow and reservoir level can also affect wildlife populations. Generally, the primary concerns relate to effects on the terrestrial vegetation downstream and adjacent to the reservoir (Oliver, 1975). The fluctuations in water level in the reservoir associated with peaking operations prevent the development of the rich plant communities that have become adapted to the natural fluctuations in water levels around lake shores and stream banks. Miller (1979) reports that peaking for hydropower nearly doubled the loss of terrestrial vegetation at the Corps' reservoir in Indiana. In some cases, a different type of vegetation, one adapted to fluctuating water levels, appears at the water's edge. Increased velocities and altered volumes of streamflow change the pattern of scouring and deposition downstream that, in turn, negatively affect wetland and floodplain habitats. Habitat and nesting areas for waterfowl are particularly threatened by such changes. With hydropower peaking, high flows downstream flood waterfowl nests along the shore, and low flows make mid-river nesting islands accessible to coyotes and other predators. The elimination of vegetation along stream banks, which commonly provide corridors for birds and mammals, is an additional adverse effect.

Hydropower peaking also causes adverse aesthetic and recreational impacts. Exposed, muddy banks, for example, often line the circumference of storage reservoirs. Sometimes the banks release hydrogen sulfide from decomposition of organic material suddenly exposed to the air, creating an unpleasant odor. An exposed drawdown zone, for example, led to a major air quality problem at Canyon Ferry reservoir in Montana. To mitigate the impact, dikes were built to create shore-zone ponds that controlled the air quality problem and also provided wildlife habitat (Childress and Eng, 1979).

Possible negative recreational effects of peaking facilities include: stranding of boat ramps; creation of wide stretches of muddy and often steeply sloping banks; dangerous currents near the dam during operation; dangerous releases of water below the dam (affecting fishermen); and inability to retain ice cover for winter sports.

In addition to its adverse effects on fish and wildlife habitat, aesthetics and recreation, hydropower peaking operations also affect water quality. Because water quality depends primarily on the concentration of various pollutants, reduced streamflow (or decreased dilution) increases the concentration of pollutants.

5. Impacts Caused by Conduits

Hydropower projects that use long conduits (or penstocks) to create hydraulic head generate a few characteristic impacts. Water diverted from a stream into a canal, tunnel, or long penstock can essentially eliminate the bypassed stretch of stream and the associated life. Man-made channels create obstacles and hazards to deer and other large wildlife. Lethan and Verzah (1971) report that, within areas of suitable habitat, annual losses of deer generally exceed one per mile of canal. Daily and seasonal migration routes may be blocked by canals and other large conduits.

6. Impacts Predominant with Large-Scale Projects

The basic components of large-scale projects are essentially the same as those for small-scale projects, and the types of impacts are essentially the same. However, the scale of impacts is greater, and impacts that may be minor with small projects may become significant. But, with large projects, mitigation is more economically feasible than with small projects. Some large reservoirs, built for water supply and flood control, have relatively little hydropower capacity because the average streamflow is low. But, because the reservoir is large, it can cause large-scale impacts. Dam safety, water quality, delayed fish migration, flatwater recreation, and reservoir evaporation are likely to be issues associated predominantly with large-scale projects.

Although downstream uses determine the potential for hazard from particular dams, the failure of large dams and reservoirs* could inundate a larger area with more force and, therefore, present a greater hazard.

Thermal stratification occurs both in natural lakes and in reservoirs that hold water for several months and where there are marked seasonal changes in temperature. During the winter and summer, such lakes and reservoirs stratify thermally with colder water in the hypolimnion (deeper areas). Water does not circulate between the layers. As biological activity proceeds, the hypolimnion may become depleted in oxygen because reaeration is reduced by the stratification. The anoxic conditions that may result are accompanied by profound changes in the chemical composition of the water, including lower pH and increased hydrogen sulfide, methane, and ammonia. In addition, the more acidic conditions that can result cause normally insoluble metallic compounds concentrated in bottom sediments to enter solution, which sometimes results in toxic conditions. Pulling water from the bottom of a stratified reservoir, therefore, may pollute water downstream and adversely affect downstream fish (Hannon, 1979).

The opposite problem--also deadly for fish--can result when surface water cascades over spillways from high dams plunging into deep pools. When that happens, air is entrained in the high-velocity flow, supersaturating the water with atmospheric gases. (Water in this condition often has a gas content of more than 110 percent of normal saturation.) Great numbers of salmon and trout--particularly the young fish--can contract the "bends' and die as a result. In recent years, however, spillway deflectors have effectively reduced supersaturation (Ebel and Raymond, 1976).

---

*The Office of the Chief of Engineers (no date) classifies as large those dams 100 feet high or higher and those reservoirs with storage of 50,000 acre-feet or more.

C. Discussion of Environmental Impacts

In previous sections the relationships between hydropower configurations and possible resultant environmental impacts were explored. In this section, details of those impacts are considered within four major categories: aquatic, terrestrial, wetlands and social. The discussion highlights the impacts identified in the generic environmental matrices in Appendix V.

1. Aquatic

Installation and operation of hydroelectric facilities has impacts in the aquatic medium through four major avenues of change: those associated with changes in stream or river flow, those resulting from the creation of impediments to fish movement, those associated with drawdown and flooding that may occur when water use for generation exceeds inflow to the storage, and those caused by supersaturation of water with nitrogen after dam passage. Each of these aquatic impacts can cause changes in the composition, abundance and distribution of the biota through a variety of specific mechanisms. The following is an attempt to identify mechanisms and impacts without attempting to judge the magnitude of the resultant change in the waterbody or in its total ecological condition.

a. Change related to flow. Changes that may occur in flow due to construction and operation of a hydroelectric facility range from complete cessation of water flow, where a channel has been by-passed, to flooding of below the dam where operations require periodic large releases, to permanent flooding with storage waters above the dam. In general, these changes in flow regime can cause direct changes in water quality and both direct and indirect ecological changes.

Major water quality effects may include the impact of flow rate on sedimentation, substrate characteristics, temperature, and oxygenation.

Flow changes usually cause redistribution of existing sediments and different patterns of distribution of new materials introduced into the system. This may result in scouring away of finer particles and their associated benthos and transport some distance from their original location or out of the system. Where the benthos are ecologically fragile, this can cause extensive mortality and reduce or eliminate certain forms from rivers or streams in which they had existed. Redistribution of sediments, whether in the channel below the dam or in the reservoir, may smother benthos and may infiltrate stones and gravel necessary to salmonid spawning and nurturing. Finer sediments deposited on the bottom in the reservoir may trap organic or toxic material, leading to anoxic or toxic conditions in the overlying waters. Waters of such quality are likely to have some impact below the dam when they are drawn off into the downstream channel.

Sedimentation may also change substrate characterisitics but more importantly, in the Pacific Northwest and in Northeastern uplands, is the impact on the gravels and stones necessary for salmonid spawning and nurturing and for food organism production. When these materials are rearranged, mortalities of salmonid fry may be a direct result. This may also cause a decrease in the use of a reach of stream for spawning where substrate characteristics become unsuitable. Reduction in spawning may lead to changes in species composition or abundance for that reach.

Temperature is a factor directly connected to flow and, closely tied to temperature, are composition and abundance of organisms. Temperature of a running stream depends upon climatic zone, proximity to the source, the character of the inputs, and the heat input to the system through man's activities and that from the sun. Whether the stream is cold or warm before installation of a hydroelectric facility, the thermal character is likely to change in the flooded area of the reservoir. The thermal character of the area downstream will change depending upon the level from which the water is drawn as it is used for generation. For example, if the stream below the dam is cool during the summer, water drawn from the upper strata of the reservoir, where it has likely increased in temperature due to insolation, will tend to warm the downstream water. Conversely, if the stream below the dam is warm during the summer, water drawn from lower strata of the reservoir will tend to cool the downstream channel. In either case, the biota which have been selectively maintained by a preferred temperature, will likely undergo a change. In their place, organisms which prefer the new temperature will thrive and those formerly extant will be reduced or eliminated.

Oxygen content of water is a critical factor in the existence of many aquatic organisms. Oxygen content of surface water depends largely on temperature, and on the exposure of the water to the atmosphere. Exposure to the atmosphere is promoted by water turbulence and circulation, itself dependent on flow. Certain stream insects thrive by positioning themselves below riffles, shallow areas of the stream where the oxygen levels are extremely high. By contrast, quiescent waters are frequently lower in oxygen than fast moving waters in the same stream. This is partly a result of temperatures increased by exposure to the sun but may also be caused by a decreased exposure to the atmosphere due to reduced circulation. Clearly, detention of water in pa storage reservoir will cause changes in oxygen content, influenced by the depth of the waters and by the phenomena associated with stratification of the storage lake. Below the dam, the oxygen content will depend a great deal on the quantity, interval and frequency of water release. This, as mentioned before in this discussion, depends upon the operation and configuration of the facility.

The primary impact of water quality change is on the biota inhabiting the stream or river before construction of hydroelectric facilities. Such change can have dramatic effects, especially in instances where the stream flora and fauna are living under marginal, stressed conditions. This can occur for example, in upland streams where temperature, dissolved solids and productivity are low and where highly adapted organisms exist. Additional stresses in the form of water quality changes may much reduce or virtually eliminate the biota in such a reach of stream. Even where circumstances are less ecologically stressed and the biota are rich, flooding with warmer water, for instance, may cause a desirable species of fish to move out and cause its replacement with a less desirable species, or vice versa. Changes in species composition, abundance and distribution can be significant and long-term impacts of hydroelectric installations must be assessed.

Where stresses are added to those found in the natural environment, it can lead to decreased production of algae and invertebrates necessary as food for higher organisms, such as fish. These lower organisms frequently live under marginal conditions, fixed or clinging to rocks or bottom surfaces in extraordinary currents, under a wide range of temperatures. These living forms also provide the essential conversion from the energy of the sun to food, or in the case of invertebrates, provide the initial conversion from plant to animal material, for use by other organisms. When environmental conditions undergo drastic change, the species composition may reflect this by changes in dominance to organisms less desirable to their predators. Fish may thus find conditions less than optimal and may move to surroundings more congenial to their requirements for health and growth.

Just as food organisms may flourish or diminish as a result of changed water quality, the effects of such dramatic inputs as the sudden rush of warm water from peaking operations may debilitate organisms and increase their vulnerability to traditional predators. This is best exemplified simply by fishes slowing up and becoming prey to fish-eating birds. Less obvious is the diminution of a predator population due to a decrease in the availability of a weakened prey.

The outcome of these changes may be a decrease in the end product of the aquatic system -- the total productivity of the water body. These impacts may begin low down on the food chain with a decrease in algal productivity, a commensurate decrease in plant feeders, a decrease in invertebrate organisms that provide food for fish and higher forms and ultimately, a lower harvest for man. This can be in the form of less productive or satisfying commercial or sports fishing.

A great deal of research effort has been exerted by such groups as the Instream Flow and Aquatic Systems Group at Fort Collins, Colorado, the Environmental Sciences Division at Oak Ridge National Laboratory, Oak Ridge, Tennessee, and the U.S. Fish and Wildlife Service in Montana, toward the goal of specifying instream flow requirements for various subgroups of organisms and needs. This intense interest reflects potential increased use of surface waters for a range of purposes, sometimes connected with augmenting domestic energy sources, including hydropower. Because of the spectrum of possible sites for hydropower development across this geographically diverse nation, it is believed that this document should establish the need for concern, not attempt to introduce new numbers or new methods relating instream flow requirements. Both data and analysis methods are contained and described in detail in the wealth of available literature.

b. Impediments to fish movement. A number of fishes endemic to the waters of the U.S. are known to develop as fry and young in fresh water and, at some point in their maturation, to migrate to the sea where they become adults, capable of reproduction. To complete the cycle, to assure maximum survival of their progeny, instinct urges the adults to attempt to return to their stream of origin to spawn. This characteristic is called anadromy and is noteworthy in the salmon, a fish of some economic importance and of great physical stamina. It is important to note that there are many lesser known fishes in which this basic instinct is found, sometimes with slight variations. In East Coast fishes such as the striped bass, shad, and the herrings, the adults spawn at the edge of fresh water, the young mature in the salinity range of 0.0 to 5.0 parts per million (ppm) salinity and in from one to five years (depending on the species), the fish return to the marine environment. In the case of the menhaden, a fish of considerable economic importance, the adults lay their eggs in the sea, near the mouth of the estuary. The eggs are then passively transported into lower salinity waters by tidal motion, developing as they travel, until they reach fresh or nearly fresh water, where they begin a maturation process that continues as the seaward-moving fresh waters carry them into increasing salinities. They mature in the estuary and return to the sea in one to two years. In the white perch (a close relative of the striped bass), the adults live in the estuary, but they move up the rivers to spawn, a much shortened process from that of the salmon and others. Another case worth notice is that of the American eel which migrates to the Sargasso Sea, in the South Atlantic to spawn. The eggs hatch there, the young mature, and as elvers, migrate back to the fresh water where they reach full maturity. This reverses the migratory direction of all other fishes and is called catadromy.

An important aspect of migration of reproductively ripe adults, development of the eggs and young and the return of the subadult fish to salt water is that at these stages they are highly vulnerable to external stresses. The adults may be more susceptible to predation and have low energy reserves; both the eggs and young are susceptible to predation and to external changes in factors such as temperature, oxygen and others. In marine and estuarine fishes of the East Coast, the zone of egg and larval fish development is the head of the estuaries where salinities range from zero to 5 ppm and it appears that the ability of these maturing fish to move freely across this range is critical. For some part of the East, especially the Cheasapeake Bay area, fresh water occurs just below the fall line, where the potential for construction of dams is greatest. In short, areas with potential for dam construction may be coincident with this critical zone.

In all the cases cited, passage into fresh water is essential to perpetuation of the species, at least in that particular location. When access to a freshwater site is blocked, the ripe adult may or may not be able to move on to another site to spawn. As we continue to encroach on possible spawning sites through erection of structures, by wetland modification, through the release of chemicals, or simply by our presence, fewer sites are available for a most significant phase of the fish's life reproduction.

There are a number of ways in which construction of a hydroelectric facility can impede fish movement, but foremost is simply erection of a dam for creation of head sufficient to turn the turbines. Since economics dictate a dam height of more than several feet and since most fish are incapable of ascending a height of more than several feet in a single effort, actual height is immaterial, existence is sufficient to prevent passage. It should be noted that a salmon may have a swimming speed in excess of 25 feet per second and able to make astonishing leaps to achieve their goal of return to their stream of origin. In addition, it is well known that the American eels returning to fresh water to mature have been observed wriggling up moist areas of dam faces, without apparent regard to dam height. Recognizing these possible exceptions, construction of a dam can make a great deal of difference in the capability of a subject species to continue reproduction in a given location by passage upstream.

Additional impediments can result from dam construction during the construction phase itself, by preparations for actual erection, by placement of coffer dams, and by initial flooding of raw earth. In addition to the physical blockage by these activities, they can cause an increase in suspended and dissolved solids sufficient to cause avoidance by migrating fish.

Impediments can also occur during operation of the facility when release waters are high in chemicals (such as hydrogen sulfide from organic breakdown, or algal products such as those secreted by blue-green algae) accumulated in the storage waters, or by release of waters of temperatures which vary greatly from those found naturally in the stream channel below the dam.

c. Problems associated with drawdown and reflooding. Hydroelectric facilities are usually operated in conjunction with other baseload power plants and when utility system demand is high or when failures occur, extraordinary use may be made of hydroelectric capability to meet demands. When emergencies occur, when demand is high or when replenishment of a hydrostorage lake does not proceed at an expected rate, stored waters may be used at a rate sufficient to expose the shallows and beaches of the impoundment. Exposure of the littoral areas of a lake or pond may have impacts on the aquatic system, depending on the length of exposure time.

It is widely accepted by limnologists (literally, those who study the dynamics of lakes) that the productivity of a lake is strongly dependent upon the ratio of shallows or of bottom area to volume of the lake. When the ratio is high, the amount of surface available for occupation by biota is great and productivity is likely to be high. Shallow surfaces provide for the attachment of the primary converters of sunlight to organic material, the algae, and more food for those animals at primary, secondary and tertiary levels which are consumers. Conversely, when a water body is very deep or has sharply sloping sides such that the shallows are minimal, the area available for occupation and for feeding is smaller and productivity will likely be low.

When drawdown occurs, an essential fraction of the productive system is removed from the aquatic sphere and returned to the terrestrial. When these littoral surfaces are exposed to the sun and air long enough to dry out, a range of impacts can result, including: die off of aquatic vegetation rooted in the shallows, death of algae in and on the exposed surfaces, mortality of the benthos in and on the surfaces, mortality of fish eggs and larval and young fish, and stranding of adult fish caught in shoreline pools during drawdown. Fish so weakened or stranded may become prey to wildlife or to scavenging birds.

If exposure of the surfaces is long term, the impact will be increased since the time required for recolonization by the biota will be extended. Where the time of exposure is such that the substrate is not dessicated, the benthos may survive and the effects of exposure will be lessened but not eliminated. This also depends in part on the frequency of drawdown and exposure, the types of resident biota and many site-specific factors.

d. Excess nitrogen. The gas content of water is a function of temperature and pressure and these factors act as described by various gas laws. In general, as temperature increases, gas content tends to decrease; as pressure increases, gas content tends to increase. When water is allowed to equilibrate with the atmosphere in shallow open containers, the gas is at saturation for the particular temperature at that time, at one atmosphere of pressure. When the temperature of a shallow, open container of water is increased, the contained gases attempt to leave the liquid, but where circulation is limited, enough of the gases may remain to place them at supersaturation, for that particular temperature. When we speak of gases in this sense, we mean the air or atmosphere, with a composition largely of oxygen and nitrogen and fractions of carbon dioxide and other gases.

In the case of terrestrial organisms, the gaseous fractions of the atmosphere are well mixed and fairly constant and except in confined spaces, organisms will have sufficient oxygen to satisfy their respiratory demands. However, in water, due to variations in temperature and pressure and their effect on resupply of atmospheric gases, the availability of sufficient oxygen is not assured. In addition, due to atomic structure, the partial pressure of the two principal gases of air, oxygen and nitrogen, differ. Nitrogen may become supersaturated more quickly than oxygen. Thus of the atmospheric gases, nitrogen is most likely to be in excess under a given set of conditions.

The reason the nitrogen content of water is especially critical is that, when nitrogen is in excess, it tends to accumulate in the blood of aquatic organisms. Under certain conditions, accumulated nitrogen forms bubbles in the blood system including the delicate gill filaments. This formation of bubbles is frequently fatal, distorting and bursting fragile blood vessels and causing hemorrhaging and blocking normal processes of reoxygenation and causing asphyxiation and nitrogen narcosis.

Supersaturation of nitrogen can occur in nature in springs, where rock strata trap and essentially pressurize the water flowing to the surface, at the bases of waterfalls, and in surface waters subject to rapid warming. Excess nitrogen can be induced in pumped waters where the pump has a faulty intake seal, in gravity lines where the drop line develops a leak, and at the spillway and outlets of a dam where the water plunges into a deep pool at the base.

In the case of hydroelectric facilities, the significance and extent of damage of such an induced gas condition depends upon a wide range of factors that are largely site specific. Mitigation of such an effect, should it be found serious, can be accomplished by certain structural changes in the facility.

2. Terrestrial

Installation and operation of hydroelectric facilities can cause three major sets of impacts on terrestrial conditions: changes which occur as a result of occupation of agricultural lands, impingment on historic landmarks and archaeological resources, and changes caused by occupation of wildlife habitat. Clearly the extent of impact depends upon a number of factors beginning with the size of the proposed facility, current land use, demography including population and potential for population shifts, and the topography. Following is a discussion of possible mechanisms of change and resultant impacts, to put them in perspective, and to provide a general basis for later consideration in a site specific sense.

a. Change due to occupation of agricultural lands. Concern is expressed here for the removal of lands currently used for such crops as cereal grains and grasses, truck crops and meat production. This loss would occur by occupation of lands through the construction of dams and reservoirs, through the erection of transmission lines and construction of means of access. In effect, these changes would prevent continued production of conventional crops and would convert to the production of electric power. This would not only cause a shift in crops but in the economic and taxable base of an area.

Agricultural lands of the U.S. are recognized as some of the most highly efficient food producing areas of the world. From approximately 400 million acres (1977) (Council on Environmental Quality, 1980), about one-fifth of the world food production and over fifty percent of the world market of wheat and feed grains are derived. Continuation of this level of production has been jeopardized due to an array of factors but in part due to conversion of cropland to other uses. This loss is estimated to be about 1 million acres per year, with well over 50 percent going to residential use and about 10 percent for commercial or industrial development. There have also been pressures to convert farmland to water uses, although more than half the land inundated between 1967 and 1975 was marginally or unsuitable for crops and only 9 percent was former cropland (Council on Environmental Quality, 1980). Where the land is indeed marginal for conventional crops, wetland use may constitute a significant environmental benefit. However, reservoir conversion can be done judiciously and with a full assessment of the relative values involved. According to a statement by the Council on Environmental Quality (1978) "If sites for reservoirs, ponds, and water retention structures are selected carefully they need not have a serious impact on food or fiber production and may become extremely productive of fish and wildlife."

b. Impingement on historic landmarks and archaeological resources. In recent years, increasing concern has been expressed by the American public toward the preservation and rehabilitation of areas and structures of cultural and historic interest. Congress has passed legislation reflecting this concern, including: P.L. 93-291, Archaeological and Historic Preservation Act of 1974; and P.L. 89-665, National Historic Preservation Act of 1966. Tphe Administration has issued Executive Order 11593, Protection and Enhancement of the Cultural Environment. The goal of these measures is to prevent further destruction and deterioration of irreplaceable areas or structures of national interest which might be sacrificed to some local economic advantage.

While it is possible to unwittingly damage or destroy cultural or archeological resources through construction and operation of a hydroelectric facility, it is also possible to increase public access to such facilities as part of the overall design of the project. Also the hydroelectric facility itself may provide a focus of interest and activity in an area which might or might not have had such a focus previously.

An additional factor is the possible advantage of rehabilitation of a dam of historic interest in itself. This possibility has been given economic incentives through the Tax Reform act of 1976, which provides for redevelopment or retrofitting while preserving the historic integrity of such an historic structure.

c. Occupation of wildlife habitat. Terrestrial impact also occurs through the preemption of space, possibly through changes induced in drainage patterns and in those changes caused by human presence alone. Such impacts act through three possible avenues: to change wildlife species composition, abundance or distribution; by obstructing "normal" paths of animal movement; and by placing additional stresses on endangered or threatened animal species.

All three avenues are influenced where river valleys or floodplains are occupied by a dam, reservoir or associated structures, where such lowlands are the preferred habitat of the species in question and where such habitat is scarce. This occupation could also have an indirect effect where the space of a principal food of a species is preempted, and where the food becomes scarce as a result.

Another impact could occur where lowland trees killed by flooding and transmission line supports provide increased perches for raptors and increased efficiencies of predation. The open space of the reservoir and the impacts of drawdown could increase the prey available to such fish eating birds as osprey. Fishes killed by stranding during drawdown may become carrion for eagles, possibly increasing populations in that group.

Additional shallows at the edges of the reservoir may increase populations of such water oriented species as beaver, muskrat, mink, otter and others. Where fluctuations in water level permit aquatics to root, moose may find sufficient food to provide sustenance.

Extensive reservoir systems and conduits which render traditional migratory routes impassable may confuse and cause large animals such as elk, mule deer or caribou to alter their patterns of movement, possibly with unfortunate impact on the populations.

The impact of such changes as have been identified may cause sufficient additional stresses on endangered or threatened populations to further endanger their existences and should be evaluated accordingly.

3. Wetlands

The principal impacts of installation and operation of a hydroelectric facility on a wetlands parallel those previously considered under aquatic impacts. However, instead of visualizing a flowing stream or river, a swamp, bog or stream-edge marsh should be pictured. These could be characterized as more or less permanently moist land, with rooted submergent vegetation in the open water, typical marsh vegetation at the water's edge, and possibly with wetlands brush and softwood trees toward fast land.

Since wetlands most often exist in low-lying lands or depressions, the probable impact if situated in a valley proposed for flooding by a reservoir would be destruction of its principal characteristics by the cover of water. Such a drastic change would kill off the submergent and marsh vegetation, and depending upon the species, possibly eventually kill the trees. The animals usually found in wetlands (voles, shrews, mink, muskrat, fox, deer, bear, and moose) would likely move on. They could be ready prey during such a move. In case this cover of water did result in destruction of a wetland, some mitigation might be derived from the fact that the reservoir would be likely to create other more extensive areas which could develop into productive wetlands. In topographical situations where a steep-sided valley would be flooded, obviously, less than ideal circumstances would exist for the development of wetlands and such an evolution would at least take a considerable length of time. In any case, wetlands loss through complete flooding should be carefully weighed with regard to the effect on the total productivity of the watershed, as well as on the immediate area.

Where wetlands lay downtream from the dam, the impacts of the facility could be several: where continuous water release could be expected, the wetlands would likely suffer minimal damage; where changes in release would be periodic and dramatic, (perhaps where the facility was to be used for peaking power) the wetlands would be subject to surges of water flowing at a higher rate than previously experienced. This would change the water quality of the wetlands through sedimentation and substrate rearrangement, and would vary the temperature and gas content of the water passing over or adjacent to the wetland. These changes in water quality could cause corresponding changes in the vegetational character, and such a change could alter the cover and food availability and result in modification in the existing fauna.

The enlargement of a wetlands through additional flooding could have the effect of a barrier to movement of some species of animals although the opportunity for alternative routes would likely prevent this from becoming a serious problem. Such a wetlands increase could make more space available for an endangered or threatened animal or plant species. By the same reasoning, a decrease in wetlands size could place enough additional stress on an endangered or threatened species to place its existence in jeopardy.

A frequent response to the question of environmental impacts of wetlands destruction is that there are already more than enough wetlands, but the very strong links between wetlands area and total productivity of even the largest bodies of surface waters should be given ample consideration. In addition, there is clearly a balance to be struck between quality and quantity of a wetlands which requires a solid background of information and a keen eye for the correct decision.

4. Social

The impacts of the installation and operation of a hydroelectric facility on the social environment stem from a number of factors: increases in general population caused by the influx of construction and operation workers and necessary personnel for increases in service industries, increased transportation activities to provide materials for the facility, increased use of local services and materials, and an increase in visitors and users of new recreational opportunities offered by the site and creation of a storage lake or pond.

The extent of infrastructure problems created by construction clearly depend upon the proposed size of the new or retrofitted facility.

Construction of new, large-scale facilities such as those in the Pacific Northwest, especially where the site is in a remote area, can have typical "boomtown" effects. These effects have been described in numerous studies. Major considerations include the impact of the temporary influx of construction and service personnel and their families on local housing, amenities such as supermarkets and gas stations, schools, water and water treatment, sewage and sewage treatment, police and municipal services and taxable property. Other impacts include the need for temporary facilities for service and materials for the proposed facility, and possible increases in access roads, railroads and equipment for transport to supply materials and services to the facility during and after construction.

An additional concern is the capability of the area to supply housing, food and services for visitors to the site and to fishermen, boaters and those with general interest in using the recreational opportunities offered by the new or retrofitted facility.

Such pressures on local capabilities must be assessed prior to actual groundbreaking and solutions must be offered to allay problems which might arise.

D. Conclusions About Hydropower

Every type of development causes some degree of environmental impact. Without analysis at specific sites, it is difficult to compare the impact of different types of hydropower projects. However, as the preceding discussion has shown, a few project characteristics make the potential range of impacts apparent and distinguish clear differences in the environmental acceptability of alternative hydropower projects. In general, then, a reasonable ranking of hydropower configurations from most to least environmentally acceptable is (1) existing conduit, (2) existing run-of-river, (3) existing storage, (4) new conduit, (5) new run-of-river, and (6) new storage (Figure 3.4).

Of the myriad environmental impacts generated by hydropower development, four categories summarize the dominant national issues: (1) the passage of fish around dams; (2) fluctuations of water level, both in the reservoir and downstream; (3) changes in water quality, and (4) effects on present land uses. The passage of fish, both upstream and downstream, is an issue that must be considered in all projects. Fluctuations of water levels are problematic where large storage reservoirs are used for peaking. Water quality is more of an issue in regions with poor water quality, such as the Ohio Valley, and regions prone to reservoir stratification, such as the southeastern United States. Issues concerning land use, including recreation, wilderness, and historic sites, are common wherever new construction is proposed.

As these conclusions suggest, regional differences are important when considering the environmental impacts of hydropower. The following two chapters address these considerations in more detail.

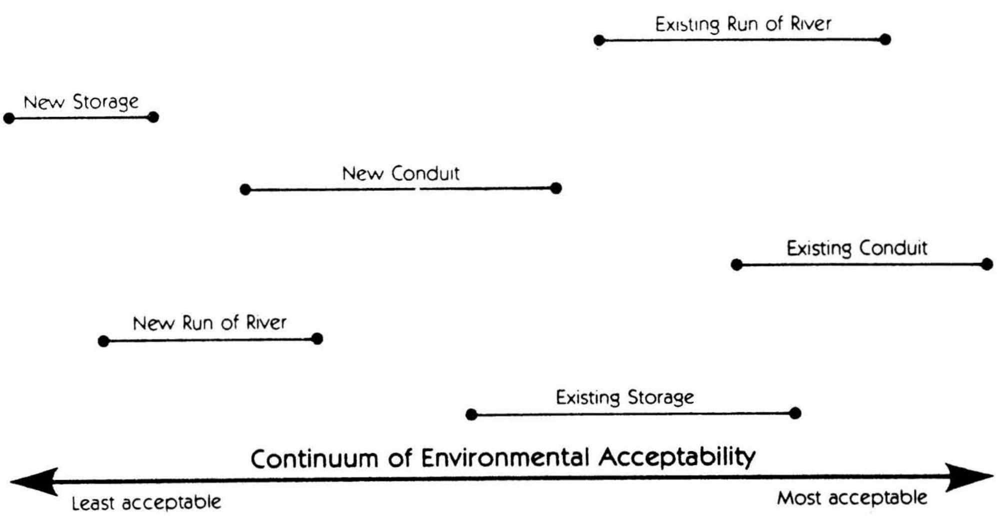


Figure 3.4 RELATIVE RANGES OF ENVIRONMENTAL ACCEPTABILITY FOR HYDROPOWER CONFIGURATIONS

E. Hydropower Contrasted With Other Energy Sources

Assuming a growing demand for electricity, other energy sources must be expanded if hydropower development cannot be achieved. Assuming that reliance on oil and natural gas should be reduced wherever possible, the possible choices will depend on the existing and proposed fuel mix found in each region. Some regions could be forced to forego plans to reduce oil or natural gas use and in fact might have to extend the life of out-dated or inefficient plants otherwise scheduled to close. Moreover, nuclear power might have to be expanded in every region to account for the deficit. Alternative energy sources--solar, wind, geothermal, or biomass--could play a minor role in overall energy supply.

The environmental impacts of diverse electric energy sources are difficult to compare, and such comparisons usually attract considerable criticism. Inhaber (1979), for example, compared the risk to human health from five conventional and six non-conventional energy systems. By considering the entire production cycle, he concluded that the risk from non-conventional sources can be as high or even higher than that of conventional sources (see Figure 3.5). His approach and use of data were seriously criticized by Holdren et al., (1979) as misleading and incomplete.

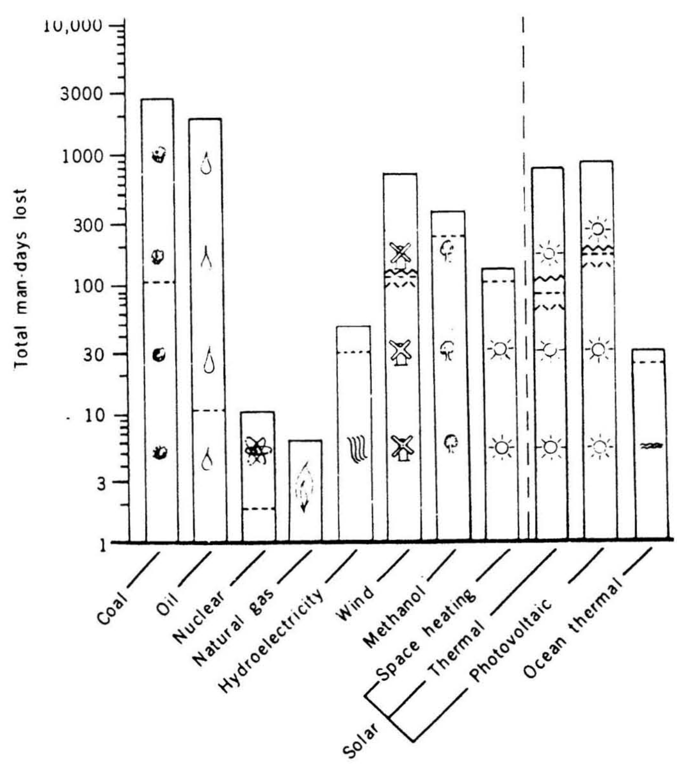


Figure 3.5 COMPARISON OF RISK (PUBLIC AND OCCUPATIONAL) AMONG ENERGY TYPES

Source: Inhaber, 1979

Few such comparisons have been made in the general literature. The reasons are simple: 1) generalized environmental data are not available and 2) dissimilar components or effects cannot be compared but only contrasted--like apples and oranges. For example, a boiling-water nuclear reactor (1000 MWe) emits various radionuclides to the atmosphere that total 7400 curies per year of radiation (McBride et al., 1978), while an oil-fired steam electric power plant (800 MWe) emits 130 tons per year of various hydrocarbons, often known carcinogens (DOE, 1980). These two kinds of pollutants behave differently in the environment, have different risks to human health, and are emitted at different rates. Therefore, these two disparate types of emissions cannot be validly compared. However, the 7400 curies emitted to the atmosphere from the nuclear power plan can be validly compared to the 1.3 curies emitted from a 1000-MW coal-fired power plant (McBride et al., 1978), if the radiation from both types of power plants is derived from a similar composition of radionuclides.

The environmental characteristics of conventional electric energy producers are summarized in Table 3-1. The various requirements of land, water, and personnel, as well as estimated total emissions are listed for a typical facility. Note that these are order-of-magnitude estimates that incorporate many assumptions about location, resource base, and environmental controls. Figure 3.6 shows how these energy types compare per megawatt dividing the characteristics by the capacity of the facility. The requirements for a hydroelectric facility exceed those for other energy types in the area of land and construction personnel. In all other areas, however, hydroelectric looks better than all others, particularly for air, water and solid waste emissions. Such gross comparisons cannot account for the damage to an ecosystem that can result from a large, peaking hydropower unit, nor can they account for the perceived public risks that can be linked to operation of nuclear power plants in populated regions or disposal of nuclear waste. Nevertheless, Figure 3.6 does provide a way of comparing energy types on a somewhat equivalent basis.

The environmental impacts of electrical generation from nuclear, coal, oil and natural gas are further amplified in the following sections. These energy

TABLE 5-1

SUMMARY OF ENVIRONMENTAL CHARACTERISTICS BY ENERGY TYPE

Energy Type	Size of Facility (MWe)	Land (Acres)	Water (Acre-Feet)	Personnel Constr.	Personnel Opera.	Total Air Emissions (Tons)	Total Water Emissions (Tons)	Total Solid Waste (Tons)[a]
Nuclear	1,000	150	21,000	670	290	670	560	200,00
Coal	500	2,000	1,400	300	130	9.200	11,000	150,000
Oil	800	170	9,800	350	170	5,000	11,000	210,000
Natural Gas	800	300	10,000	780	120	400[b]	1,900[c]	Negligible
Hydroelectric	200	6,000[d]	0	260	20	Negligible	Negligible	0

[a] Does not include overburden removal.
[b] North Carolina Departemnt of Commerce, 1979.
[c] University of Oklahoma, 1975.
[d] Including reservoir.
Source (except where otherwise stated): DOE, 1980.

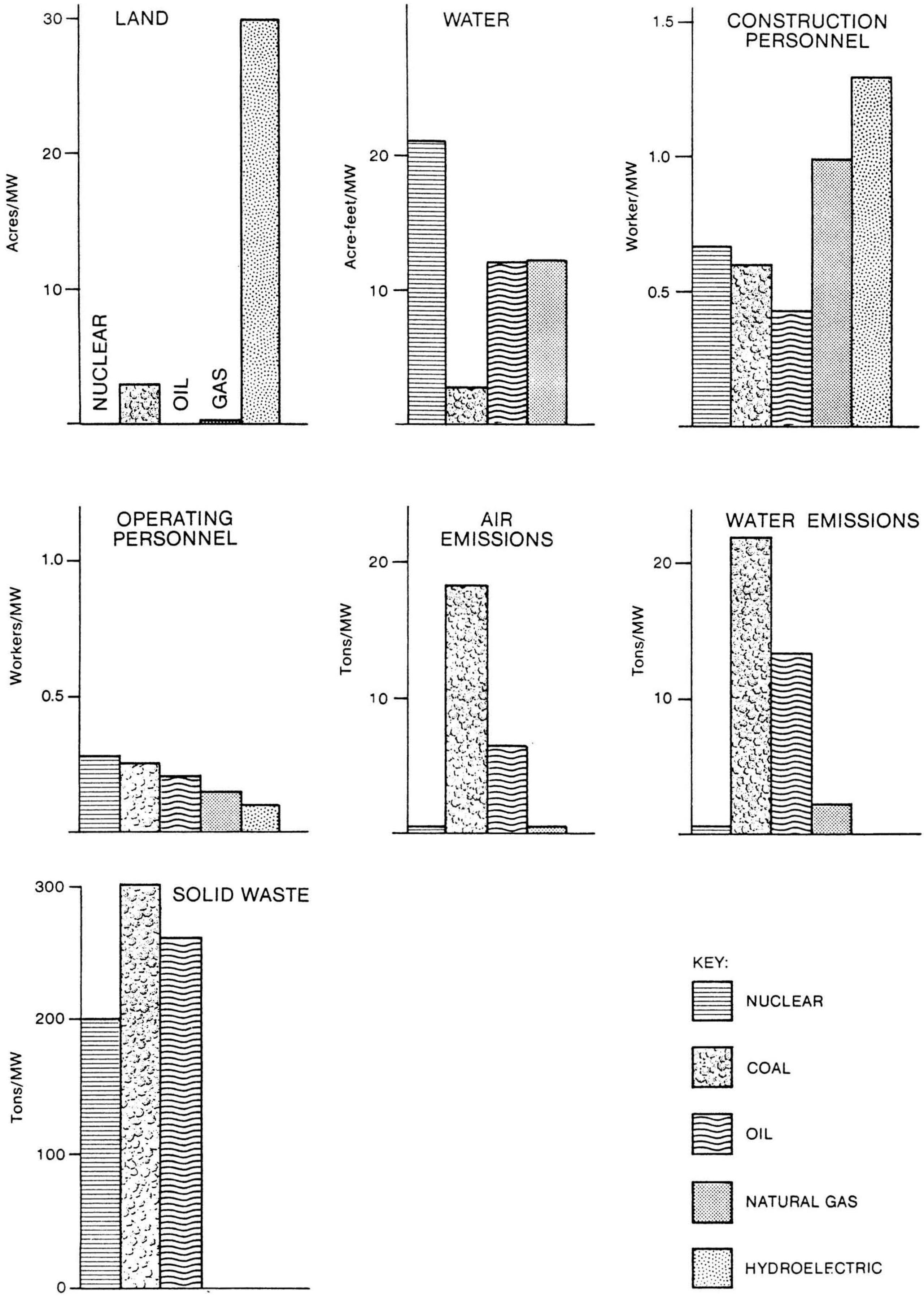


Figure 3.6 COMPARISON OF ENVIRONMENTAL CHARACTERISTICS AMONG ENERGY TYPES

Source: Derived from DOE, 1980.

Note: The value is negligible if none is shown.

types would have to pick up the load expected to be carried by projected hydropower development. Environmental impacts of these sources are identified in each step of the energy production system, e.g., extraction of the energy source, processing, transportation, power plan conversion, and distribution to end use consumers.

1. Nuclear Power Generation

Extraction: About 60 percent of the uranium ore mined in the United States is taken from open pit mines while deep mines supply the balance. Because most of the uranium reserves are found in deep deposits, the number of underground mines is expected to increase in the future (Brookhaven National Laboratory, 1976).

The major air pollutants from uranium mining are radon-22 and dust (U.S. Atomic Energy Commission, 1979). Although this gas is readily diluted above ground, fans to move large volumes of air and special vents are required to reduce these concentrations underground. Occupational death and injury rates are greater for underground miners than for those working in open pit mines. contamination of surface water by silty, low pH, and radioactive elements can result from either open or deep uranium mining, although they are more likely to occur with open pit mines (U.S. Department of Commerce, 1977).

Generation: The two major environmental problems at reactor sites are the release of large quantities of waste heat and the possible release of radioactivity. For every unit of electrical energy produced, a nuclear generating station releases about two units of waste heat. This heat is released either into the atmosphere through cooling towards, or into the aquatic environment. In the latter case, the heat can be transferred to a river or lake by pumping a portion of the water in the river or lake through the plant's cooling system. This results in a significant temperature increase in the river or lake in the immediate vicinity of the station. Such thermal impacts can have serious localized effects on aquatic organisms. Some generating units use cooling ponds whereby the same water is used repeatedly for cooling, with only a small amount of make-up water being drawn from rivers or lakes. In this case, the heat is dissipated into the atmosphere from the pond surface. Fog and rain may be enhanced in some areas by wet cooling towers, which emit water vapor into the air. If the source of water for wet cooling towers is salt or brackish water, salt deposition within a few miles of the tower may be a problem (U.S. Department of Commerce, 1977).

Radioactive nuclides may escape in minute quantities into the coolant from small leaks in the fuel rods. From there, the nuclides may pass into the reactor's liquid or gas effluent stream, depending on the solubility of the nuclide and the type of reactor. The bulk of the released radioactivity is in the form of noble gases released to the atmosphere, such as krypton and radon (U.S. Atomic Energy Commission, 1974).

Most reactors produce several thousand cubic feet per year of low level radioactive waste that must then be consolidated and buried. This waste is typically composed of sludges and resins from the liquid filter systems, used air filters and contaminated clothing, paper, rags and other miscellaneous items.

2. Coal-Fired Generation

Extraction: Coal mining produced 670 million tons nationally in 1978. Currently, about 64 percent of the coal mined in the United States comes from surface strip mines, and the remainder from underground mines (DOE, 1979c).

Dust, the primary air pollutant from surface mines, is carried into the atmosphere by wind erosion of the disturbed soil. However, the human health impacts from dust are much more severe for undergrouund mines, in which inhalation of dust particles results in severe respiratory problems that can lead to decreased life expectancy for miners (U.S. Department of Commerce, 1977). In addition, methane gas is found in underground mines, and is a potential source of fires or explosions.

Acidic water runoff and increased water turbidity are the main sources of water pollution from underground mines. Sulfuric acid, iron salts, and suspended solids from surface mine operations can be discharged in sufficient concentrations to destroy all life in the streams in the vicinity of the mine (U.S. Department of Commerce, 1977). The degree of impact depends on the slope of the land and on the variability of local precipitation. Recent experience indicates that this impact can be controlled if proper land reclamation techniques are employed and if mining of steep slopes is restricted.

In underground mines, disruption of land is minor, because the rock and soil overlying most of the mine is left in place. However, removal of the coal may cause land subsidence, which in some cases removes the land from all other productive uses. Land disruption in surface mining comes directly from stripping away the soil and rock to remove the underlying coal. Under adequate precipitation, land reclamation can be successful if adequate care is taken. In relatively flat land, the topsoil can be stored and replaced during reclamation. Reclamation in the more arid areas of the west has been demonstrated to a successful degree in a few instances. In hilly and mountainous terrain, however, reclamation of strip mining areas is more difficult because of unstable slopes and poor soil conditions.

Processing: Processing of coal ore includes crushing, sorting by size, removal of non-carbonaceous rock, and washing. Dust and particles may be released during either process. Unless the water used for washing is impounded or filtered, it may carry large amounts of fine coal and rock particles into local streams or rivers, greatly increasing turbidity. Adequate methods are available and in use to control pollutants, and land disposal is required for the collected material.

Generation: The burning of coal to produce steam releases into the atmosphere such emissions as sulfur dioxide, particulates, heavy metals, carbon dioxide, nitrogen oxide, hydrocarbons, and possibly radioactive materials (U.S. Department of Commerce, 1977). The bulk of the ash consists of silica, alumina, and ferric oxide. While none of these materials is harmful in large pieces, they are suspended in the air as very fine particles and significantly reduce visibility. They also can cause increased requirements for cleaning and painting costs in the vicinity of the power plant, and enhance the deleterious effect of the emission of sulfur and nitrogen oxides by serving as condensation nuclei for acid droplets.

Coal mined in the United States varies in sulfur content from less than one percent to over four percent, with most of the western coals ranging from one percent to two percent sulfur content (Hittman Associates, 1975). Essentially all of the sulfur is oxidized to SO_2 when the coal is burned. The removal of sulfur dioxide from stack gas at a large power plant is becoming increasingly effective with between 80 percent and 90 percent removal now achievable. Such control equipment will probably be required for all new plants. In addition to sulfur dioxide emissions, the generation of electricity from coal also releases some trace amounts of heavy metals, such as mercury, lead and zinc--all of which are released as fine particles.

Thermal heating of the cooling water is one of the water resource impacts of coal-fired steam plants. The amount of heating can be reduced by cooling towers to dissipate waste heat thereby minimizing the impacts to aquatic life. However, cooling towers reduce energy generation and may also enhance fog and increase local precipitation. Fly ash that is scrubbed from the stack gas as well as the heavier ash from the combustion changer must be removed from the plant site. Although some of the metal wastes may sometimes be reclaimed, the bulk of it is disposed. The land use for the disposal is generally unproductive for other purposes for many decades. The emission of heavy metal compounds into the air may also be a problem. Some commercial crops (e.g., lettuce) can take up heavy metal residues deposited on leaves during fallout. Also, acid or heavy metal contamination of underground or surface water, and silting of rivers and streams may result from improperly located or managed ash disposal sites (U.S. Department of Commerce, 1977).

3. <u>Oil-Fired Generation</u>:

<u>Extraction</u>: Extraction of oil involves exploratory drilling and development of production wells. Since oil wells often contain natural gas as well, the impacts associated with natural gas also apply to a smaller extent.

Air quality is essentially unaffected by oil extraction except in local areas when blowouts, burning or flaring occur. Air emission from these events include CO, CO_2, NO_x, SO_x, hydrocarbons, and particulates (U.S. Department of Commerce, 1977). Considering the entire oil energy system, the emissions from other stages are relatively benign, although local impacts can be significant.

Air pollution from refining depends on the composition of the oil, which varies from source to source. In most cases, however, large quantities of SO_2, CO and hydrocarbons are generated. Smaller quantities of NO_x and particulates are emitted (U.S. Department of Commerce, 1977). Sulfur dioxide is primarily generated in a catalytic cracker and can be significantly reduced by hydro cracking or by removing sulfur from feedstocks. Hydrocarbon and NO_x emissions can be reduced if proper combustion control measures are employed. Emissions of trace elements, such as lead and nickel, also occur in small quantities.

Water quality can be degraded by both continuous discharges and blowouts of crude oil and brine. Ground water can be contaminated directly by the brine, or by seepage from the well through the rock formations. For offshore operations, the dissolved solids from the brine become pollutants. Blowouts cause the most serious impacts because oil usually contaminates the local area. Blowouts are more common at offshore sites (Kash, 1973).

Water pollution from oil refineries is composed of dissolved and suspended solids, such as dirt, sludge and salt and non-degradable oil and phenols. The degree of impact from BOD and chemical oxygen demand on the local surface water is significantly reduced if the wastewater is treated before discharge.

Generation: The impacts of burning petroleum to produce electrical energy are of local concern. The primary air pollutants are SO_x, NO_x, particulates, and various hydrocarbons such as benzene and styrene. Water pollutants include solids, acids, hydrocarbons, and heated water, which are proportionate to the amount of energy produced (U.S. Department of Commerce, 1977).

4. Natural Gas

Extraction: Natural gas is composed primarily of hydrocarbons, methane and impurities, such as water, gaseous sulfur compounds, nitrogen oxides, and carbon dioxide. It is sometimes found in association with crude oil; thus, the technology for extracting natural gas is similar to that of crude oil. The primary air emissions from natural gas production are nitrogen oxides, which are released when the fuel is consumed to run compressors and when the gas is vented or flared (DOE, 1979c). About one percent of the gas is lost in production methods, including flaring and venting. Offshore losses from production have been higher than for onshore wells due in part to the cost of transporting small quantities of gas to an onshore collection point.

The sources of water pollution from natural gas production are drilling material such as mud, water, sand, chemical wastes from drilling operations, well blowouts and leaks, and construction impacts. These impacts are generally minor when compared to corresponding impacts of the petroleum system (U.S. Department of Commerce, 1977).

Processing: The emissions associated with natural gas processing depend on the form of the gas. For dissociated dry natural gas, minimal processing is required prior to transportation. If the gas is found in association with crude oil, or if the gas contains large amounts of impurities, processing plants are constructed to separate the components. Emissions to the air are mainly nitrogen oxides plus some particulates, hydrocarbons, sulfur oxides, and carbon monoxide (U.S. Department of Commerce, 1977). In total, the mass of the emissions is only a small percentage of the emissions generated by refining an equivalent amount of oil (based on heat content).

Water quality is not affected significantly, although some contamination occurs from caustic wastes and lubricants. Thermal pollution may occur locally or through the process of desulfurization, but usually is not a serious problem.

Generation: The primary impacts of gas turbine facilities are nitrogen oxide emissions and the noise of the turbines. The latter impact is the most serious of the two from both occupational and siting considerations, but this impact can be reduced by proper siting and building construction. Natural gas is considered to be the cleanest energy fuel and causes only minor, local degradation of air quality. Water quality is not significantly affected.

CHAPTER 4

REGIONAL ENVIRONMENTAL PROFILES

A. Introduction

Because the United States contains great geographical diversity, the country has been divided in this report into seven regional study areas, each with distinct environmental characteristics. Such distinctions enable the analyst to consider hydropower impacts and issues that vary by region. Objectives were (1) to identify regional differences in environmental sensitivity to hydropower, (2) to provide an environmental data base that can be used in planning and (3) to provide a regional basis for evaluating additional hydropower capacity.

Figure 4.1 shows the regions used, which were established mainly on the basis of broad-scale ecosystem differences within the United States, and the regional magnitude of potential hydropower development. Dominant plant and wildlife communities represented one consideration in identifying regional boundaries; others included major water basin boundaries, U.S. Fish and Wildlife Service areas, and National Electric Reliability Council Regions. The study areas were also adjusted to maintain state lines. Appendix D presents a detailed discussion of the methodology for selecting boundaries.

Environmental profiles were developed for each region. The four environmental factors used in the environmental matrix in Appendix F, water quality and use, aquatic ecology, terrestrial ecology, and land use and recreation, are addressed. For each factor the key environmental issues and concerns regarding hydropower are identified. The profiles provide the background for postulating the regional environmental impacts associated with developing the hydropower projects recommended for further study in the NHS regional reports.

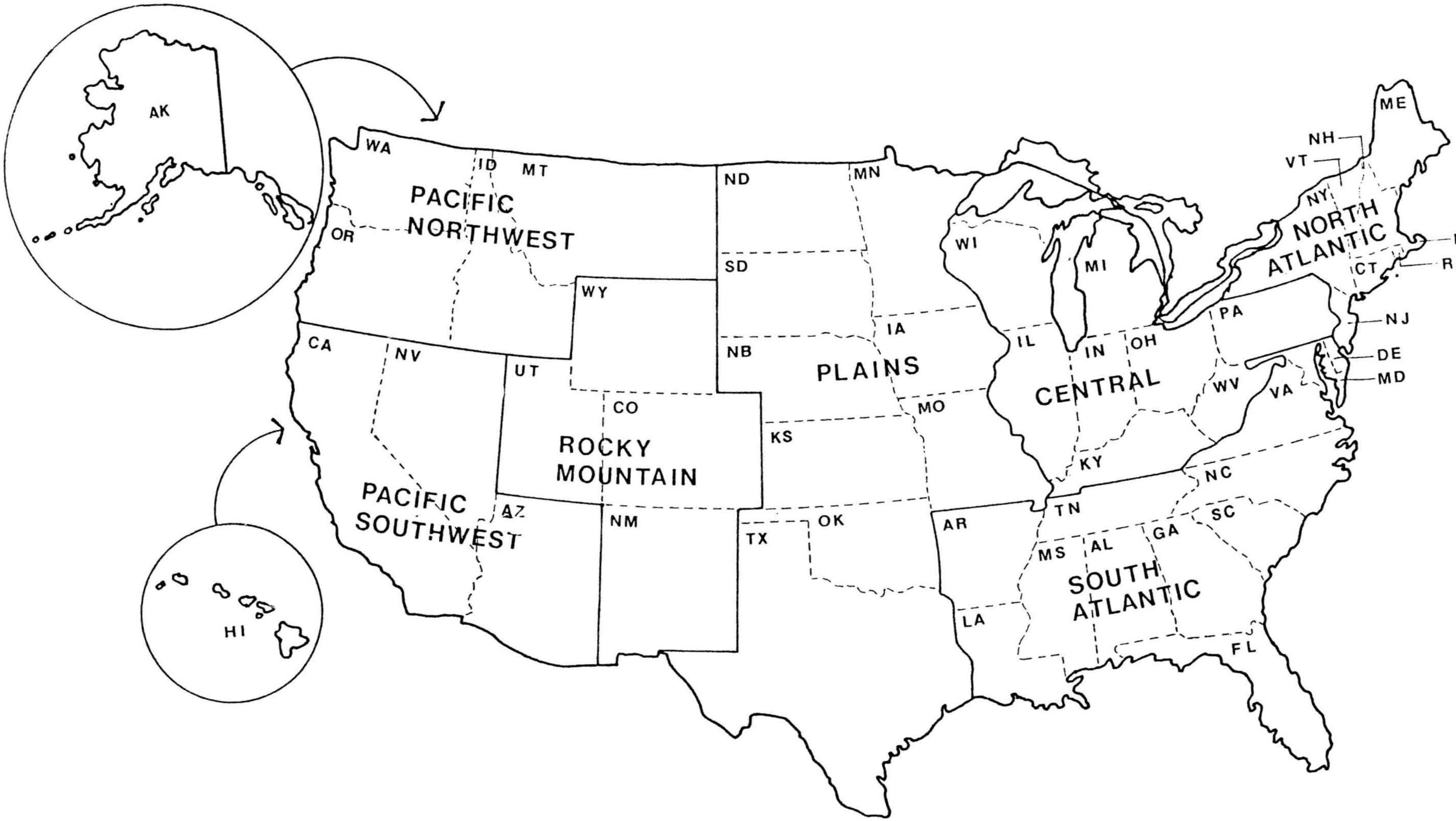


Figure 4.1 REGIONAL STUDY AREAS

B. Pacific Northwest Region

1. Overview

The Pacific Northwest includes the states of Alaska, Idaho, Oregon, Washington, and Montana, which together cover more than one-quarter of the total area of the United States.

Hydroelectric sources supplied 85 percent of the region's energy in 1976. Hydroelectric generation, including resources under construction, brings the total capacity to 29,000 MW (BPA, 1977). Washington produces nearly two-thirds of the region's electricity, and Oregon produces nearly 25 percent. Alaska contributes less than 2 percent.

The Pacific Northwest is estimated to hold about one-third of the nation's total hydroelectric potential. Most of the region's desirable sites, however, have already been developed. The continental portion of the region contains 58 major* hydroelectric dams of which 30 are federally-owned facilities that produce about half of the electricity consumed in the area.

Electric power has traditionally been an inexpensive source of energy in Idaho, Oregon, and Washington, supplying most of those states' demand for electricity. But, because of expected growth in the power load, the region will probably come to rely more heavily than in the past on thermal electric generation, with hydropower contributing to help meet peak demand.

2. Water Quality and Use

a. Description

The Columbia and Snake rivers currently provide hydropower, fish and wildlife habitat, recreation, transportation, and water for irrigation and industrial and municipal purposes. Conflicting desires for power, irrigation,

---

*Producing more than 30 MW of electricity.

and anadromous fish runs frequently make water use a sensitive issue within the region.

About one-fourth of the water in the Columbia River Systeem originates in Canada and traverses the Northwest, making water resource management an issue of major importance among states and between nations.

b. Issues

Hydropower development within the region has changed flow conditions in once free-flowing rivers, often with adverse effects on river biota. One of the most adverse effects in the region is the alteration of the flow regime downstream, which leads to changes in erosion patterns, flooding characteristics, and the stream bed and bank material with ultimate impacts on the aquatic habitat. Another common effect downstream is the degradation of water quality including temperature. Although minimum flows have been established by some government agencies, downstream water temperatures vary widely when deep cool waters are withdrawn from reservoirs for power generation or when low streamflows during off-peak demand periods allow increased solar warming. The withdrawal of deep waters in storage reservoirs often releases water that contains low concentrations of dissolved oxygen. In the past, gas saturation has occurred in water released over spillways at high dams. Spillway deflectors, however, have reduced the problem. Diversion of water through turbines to generate power does, in fact, minimize the problem.

3. Aquatic Ecology

a. Description

A distinguishing feature of the Northwest Region is its anadromous fishery resource. Steelhead trout, and chinook, Coho, sockeye, chum, and pink salmon are common throughout the area. American shad, striped bass, green sturgeon, and smelt are also present. Freshwater resident fish include rainbow, brown, lake, and brook trout, together with mountain whitefish, white sturgeon, and sunfish. Some warmwater species are black and white crappies, and smallmouth and largemouth bass (U.S. Fish and Wildlife Service, 1976a). In addition, one of North America's largest, apparently self-sustaining paddlefish populations occupies the Missouri River below Ft. peck dam and the Yellowstone River below Intake, Montana. Within the estuaries and coastal habitats are found perch, flounder, various kinds of shellfish, herring, and shad. Shrimp and dungeness crab are important sport and commercial shellfish.

b. Issues

The decrease in fisheries is often a source of controversy; along both rivers, large runs of salmon and steelhead trout have traditionally provided food for Native Americans and income for commercial fishermen. Both groups have been vocal in their efforts to preserve the source of their livelihood. In particular, Native Americans are making claims on water uses and fishing rights to reestablish or maintain their cultural heritage. The recent Bolt-Phase II decision found that Native Americans have the right to nondegradation of fishery habitats.

New hydroelectric generators could threaten the already declining salmon populations in the Columbia and Snake River systems. Continued hydroelectric expansion could threaten fish populations by (1) killing fish that pass through turbines, (2) destroying spawning areas, (3) increasing variability in river flows during peak-power generation, and (4) increasing predation because fish will require more time to negotiate stillwater reservoir pools (EDAW, Inc. 1978-80).

Another central issue in the region is the cumulative impact on fish that must encounter several dams (nine on the Columbia and six on the Snake River). The impacts are greater from a series of dams on the same river as opposed to dams distributed on several independent river systems (U.S. Department of Commerce, National Marine Fisheries Service, 1974). Certain management practices within the Northwest have had considerable impact on stream fisheries preservation. Hatchery production and fishery stocking have been moderately effective in maintaining resident fish species. Three major influences, however, adversely affect fisheries preservation: (1) high velocity streamflows, which are suddenly released through turbines and have sometimes offset the fishery benefits of low-flow maintenance, (2) reduced watershed yield, which has severely constrained fishery preservation, and (3) increased post-project flow fluctuations, such as those that have accompanied hydroelectric power generation even when minimum flows were maintained (U.S. Fish and Wildlife Service, 1976a).

In the Missouri River Basin, further impoundments or barriers on the lower Yellowstone and Missouri Rivers could jeopardize the continued existence of the paddlefish population.

4. Terrestrial Ecology

a. Description

The diversity of plants and animals in the region reflects the enormous variation of climate and habitat types, from Arctic tundra to sagebrush and grassland. In addition, many introduced plant species are interspersed with native vegetation, resulting in a mosaic of wildlife communities. The region's terrestrial ecosystems are joined with the marine ecosystems along the coasts and, particularly, on Puget Sound. The area contains thousands of coastal miles of bays, mudflats, sand dunes, and estuaries, supporting commercially valuable species.

The region constitutes a significant portion of the northern flyway, containing such western waterfowl as the Canada goose, mallard, canvas back, woodback, and cinnamon teal duck. Typical mammals include mule deer, caribou, white-tailed deer, moose, black bear, elk, and signficant commercial fur-bearing animals, such as mink, beaver, muskrat, river otter, and raccoon. The wildlife resources are particularly valuable in Alaska.

Threatened or endangered species in the region are the Columbian white-tailed deer, Aleutian Canada goose, brown pelican, American peregrine falcon, northern Rocky Mountain wolf, whooping crane, bald eagle, and grizzly bear (DOE, 1979b).

b. Issues

The effects of hydropower peaking operations on riparian habitats and, in particular, wetlands are major concerns in the Northwest. Impacts stem from the increase in fluctuations of water levels along water courses. For example, land bridges are formed to river islands during low-flow periods, resulting in increased predation in waterfowl nesting areas.

The loss of riparian edge is particularly acute in the more arid areas east of the Cascade Ranges, where there is little woody vegetation. The areas are important wildlife migration routes, and the loss of such resources produces serious impacts on terrestrial wildlife. The difficulty in reestablishing riparian vegetation along shorelines of newly created reservoirs is also a key issue. Fluctuations of greater than three feet, create insufficient water in reservoirs to nourish root systems of riparian vegetation.

Transmission corridors alter habitat along the right-of-way. The interruption of migratory patterns for, as an example, caribou and moose in Alaska are repeatedly identified in the literature (U.S. Department of Commerce, 1974).

5. Land Use and Recreation

a. Description

About two-thirds of the region is publicly owned and managed, enabling the development of effective land management programs and extensive outdoor recreational opportunities. The federal government owns about one-half of the region's land, including approximately two-thirds of the land in western Montana and Idaho, one-half of the land in Oregon, but less than one-third in Washington (DOE, 1980). The U.S. Forest Service and Bureau of Land Management (BLM) control most of the federal land and manage much of the region's forest and rangeland. Smaller areas of federal land are managed by the Bureau of Indian Affairs, including 29 Indian Reservations.

Rivers within the Washington, Oregon, Idaho, and Montana area that have been identified as federal wild and scenic Rivers are the Scagit, portions of the Rogue, Salmon, and Rapid Rivers, the St. Joe, the Clearwater, portions of the Missouri, and the Flathead River in Montana. Other rivers under study for designation are the Priest, the Moyie, portions of the Snake, the John Day, the Salmon, the Bruneau, and the Owyhee (U.S. Department of Interior, 1979).

b. Issues

Visual intrusion from transmission lines, rights-of-way, and powerhouses is a major land-use issue in the Pacific Northwest. Preservation of the wilderness character and wild and scenic rivers is a predominant concern of many residents there. New construction for peaking power plants, therefore, may provoke complaint from residents. Construction could also alter future land uses along the shore upstream and downstream of the dam. Instream uses may also be affected because of sudden fluctuations in water levels.

Public interest in outdoor recreation has created considerable concern for the retention of remaining free-flowing rivers. Hydropower facilities that maintain historic streamflow in the natural channel, with periodic releases especially for white water users, may offer a feasible compromise.

In Alaska, the influx of construction workers could strain services in the more remote areas. In addition, outsiders may not get along with old-time residents, who might resist the social change that could accompany the arrival of new workers.

C. Pacific Southwest Region

1. Overview

The Pacific Southwest region contains the states of California, Nevada, Arizona and Hawaii. Most of the major rivers of California drain the western slope of the Sierra Nevada mountain range, and it is on those rivers that the great bulk of the existing and potential hydropower generation exists.

Hawaii is unlike the rest of the region, but was included here because of its relative proximity to the other states.

Because the mountain systems in the area are still young and growing, seismic activity is an important concern regarding hydropower development. The design and location of dams thus become critical considerations in the region. The Auburn Dam on the American River represents a prime example of a facility delayed because of concern about earthquake safety (Hunt, 1974).

In 1979, the actual installed hydropower generating capacity for California, Nevada and Arizona was approximately 8,500 megawatts. The total has been projected to increase by an additional 1,000 megawatts by 1989 (National Electric Reliability Council, 1980). Energy use in the region uniformly shows a growth rate less than the national average; on the whole, the region has much less energy consumption per capita than the nation. California is the major energy user in this region, accounting for about 83 percent of the regional energy consumption in 1975 and 80 percent projected for 1990 (DOE, 1979b). Consequently, most of the present and projected environmental impacts associated with hydropower will probably be in California, particularly within the Sierra.

In Nevada, projections of additional hydroelectric capacity are small. If the capacity is to be increased, proponents of hydropower will have to compete with farmers and ranchers for already scarce water resources. In Arizona, the DOE (1979b) forecasts no increase in hydroelectric generating capacity by

1985. A slowdown of electricity demand and inadequate capital commitments have postponed, for example, the Montezuma pump storage plant in Arizona.

Hawaii depends almost completely on oil for its energy. In fact, oil constituted 92 percent of Hawaii's total primary energy supply in 1975. The remaining eight precent came from two other sources--hydroelectric generation (one percent), and bagasse-fired electrical generation (seven percent). (Bagasse is a residue produced from the processing of sugar cane.) Projections for future energy consumption alter the current picture slightly; by 1990, petroleum's share of the market is expected to diminish to around 78 percent, with natural gas capturing a 13 percent share; bagasse, seven percent; and coal, one percent.

Some of Hawaii's small streams have potential for run-of-river hydropower development. However, they frequently have important environmental attributes. Also, a considerable amount of surface water is diverted from streams, primarily for agriculture and irrigation. The Corps has already conducted preliminary feasibility studies for a group of stream sites in Hawaii. At present, greater attention is now being focused on hydropower development on the Wailua River, Kauai Island.

2. Water Quality and Use

Fluctuation in streamflow below dams, as created by water resources development, is a major problem in the Pacific Southwest region. Because the majority of such development is for water supply projects, adding hydropower to existing facilities would not further deteriorate the streams unless the pattern of water releases was changed substantially. However, the construction of new dams and impoundments could severely deteriorate some free-flowing streams.

Water resources in the region are highly developed and heavily used. Irrigation water for agriculture is by far the major use, amounting to roughly 75 percent of the region's total consumption (Todd, 1970). During years of average streamflow, total water demand (consumption plus instream flow use) exceeds supply in all parts of the region except Northern and Coastal California and Northeast Arizona. During dry years, water demand exceeds supply by 103-315 percent in all areas except the northwest corner of California (U.S. Fish and Wildlife Service, 1976b). The creation of reservoirs for hydropower could be a significant benefit if water supply were added as a purpose of each facility.

Groundwater is the chief source of water for agricultural and urban use in Hawaii. While now locally abundant, fresh water may be in shorter supply in the future, and is viewed as a potential limiting factor to Hawaii's growth and development. Agriculture, industry, and rapidly growing residential and visitor populations place excessive demands on groundwater supplies, particularly during periods of unusually low rainfall. The great majority of the population in Hawaii resides on the island of Oahu, in or around Honolulu.

3. Aquatic Ecology

a. Description

In California, the major anadromous fish species are chinook, chum, and Coho salmon, steelhead trout, striped bass, American shad, and searun cutthroat trout. They inhabit the coastal streams of Northern California and the Sacramento-San Joaquin Delta region. Resident coldwater fish species include rainbows, cutthroat, brown, and brook trout. Common warmwater species include sunfish, black and white crappie, largemouth and smallmouth bass, and catfish. Coldwater fish inhabit the lakes and streams of the northern Coast Range and the Sierra Nevada Mountains; warmwater fish are found throughout the southern and central parts of California.

Important estuarine fish are northern anchovy, flounder, smelt and Pacific herring. Estuaries serve as breeding, rearing, and feeding areas for these and many anadromous species, as well as for shellfish, crabs, and shrimp (U.S. Fish and Wildlife Service, 1976b).

Most streams in Nevada empty into desert lakes. Stream fishing is limited; most sportsmen in Nevada fish the larger lakes and man-made reservoirs. Within the fish population, coldwater species predominate. Warmwater species such as catfish, walleye, white and largemouth bass are found only in waters at lower elevations.

In Arizona, introduced spiny-rayed warmwater fish are the dominant species. The rainbow trout is the most widespread game fish. It and other species of trout are largely maintained through artificial propagation.

Hawaii's native stream life is particularly well adapted to the rocky, precipitous, freshet-flow streams. Six fish species predominate, along with two mollusks, two shrimp, and a polychaete worm. Among the fishes, the goby is on the American Fisheries Society list of rare and endangered species, and three other species are considered threatened.

b. Issues

California endangered fish species include the Mohave chub, the Owens River pupfish, the tecopa pupfish, the unarmored, three-spine stickleback, and the Lahontan and Paiute cutthroat trouts (U.S. Department of the Interior, 1977). In Nevada and Arizona, some unique and distinctive ecosystems contain threatened or endangered fish species, including the Pahranagat bonytail, the Cui-ui, the Moapa dace, the Pahrump killifish, the Devil's Hole pupfish, the Lahontan cutthroat trout, the humpback chub, the Colorado River squawfish, the Gila topminnow, the Arizona trout, the woundfin, the leopard darter, and the Warm Springs pupfish.

Ninety percent of the aquatic fauna in the Pacific Southwest region is endemic. In California from 1940-1970, the principal fish stocks declined approximately as follows: steelhead - 80 percent, silver salmon - 65 percent, and king salmon - 64 percent (U.S. Fish and Wildlife, 1976b). Causes for the declines include:

- o Passages to spawning and rearing habitats blocked by dams and other instream structures.
- o The diversion of juvenile fish from their stream habitat into water supply conduits, preventing their survival or the continuation of their normal life processes.
- o The destruction of physical habitat by use of the watershed, e.g., logging, grazing, urbanization, and waste discharge to streams.
- o The conversion of marshes and wetlands to agricultural and urban uses.
- o The reduction of life-supporting habitat and loss of spawning beds through adverse alterations in instream flow.

The greatest loss to fisheries is directly related to the removal of greater than 30 percent of the flow from the downstream channel by diverting water from the reservoir into conduits, rather than using the downstream channel for conveyance. Often the water is diverted to another watershed. Single-purpose power and municipal supply projects appear to divert water from the reservoir more frequently than other facilities (EDAW, Inc., 1978a).

Ten percent of the average flow (90 percent depletion) is enough to sustain short-term survival habitat. However, some portions of the region are already experiencing greater than 90-percent flow depletion in average years. Southern Arizona, for example, shows a depletion of more than 100 percent. Consequently, people there are pumping groundwater at rates in excess of natural recharge to meet current offstream consumption. Other areas in the region would be much more severely stressed if groundwater were not being overdrawn to supplement normal surface water supplies. For example, projections show that the San Joaquin Valley headwaters will be severely depleted by the year 2000 (U.S. Fish and Wildlife Service, 1978b).

In Hawaii, the greatest threats to stream ecosystems stem from the loss of native species, in part from competition by introduced exotic species better adapted to channelization and resulting water quality modifications. Dewaterment represents an equally significant threat that will become more severe in the future, when groundwater use reaches peak potential. Stream diversions have been particularly significant on Oahu and Maui; Molokai and Kauai have also been affected. The threat of stream dewaterment has prompted federal and state officials to consider the adoption of minimum streamflow standards or criteria to ensure a balance between consumptive uses and beneficial instream uses or values (fish and wildlife, recreation, aesthetics, etc.). This issue is expected to come to a head within the next decade.

4. Terrestrial Ecology

a. Description

California winters 50 to 80 percent of the waterfowl on the Pacific Flyway. Waterfowl often seen in the region include black brant, cinnamon teal, wood duck, widgeon, pintail, scaups, scoters, ruddy duck, mallard, gadwall, greenwinged teal, and shoveler. Occasional sightings are made of Canada goose and whistling swan (U.S. Fish and Wildlife Service, 1976b).

Other wildlife that frequent water sources include deer, antelope, elk, moose, and bighorn sheep.

In Nevada, waterfowl are concentrated in a few large marshes fed by freshwater streams. Waterbirds, including white pelican, phalaropes, sandhill crane, herons, American avocet, ibises, and gulls use these terminal lakes and marshes. Beaver and other riverine fur animals are found along the headwater streams.

In Arizona, waterfowl and cranes concentrate in the wetlands and marsh areas of streams and impoundments, primarily during fall and winter migration periods. The Mexican black duck, whooping crane, and Yuma and Clapper rails are the endangered bird species that use riverine wetlands. Maintenance of riparian habitat is of primary importance to those species.

In Hawaii, the abundance, distribution, and characteristics of terrestrial ecosystems are dominated principally by rainfall, elevation, slope, age of the predominantly lava substrates, climate, and geographic isolation. The last factor, in particular, has led to the establishment of a largely endemic terrestrial biota. Tropical rainforests support wildlife (particularly endangered native Hawaiian waterbirds) which characterize lower reaches of some watersheds. Hawaii is remarkable in having the highest proportion of endemic plant species in the United States.

b. Issues

The potential for conflict between energy facilities and rare and endangered species in the region is high. California alone has a total of 44 endangered species and 16 threatened or rare ones; new fish, wildlife and plants are being added to the list all the time.

The 1,000 additional MW of hydropower that is needed for California during the 1980s (National Electric Reliability Council, 1980) would convert 4,200 acres of valuable mountain wildlife habitat into aquatic (reservoir) habitat, hence altering land use and open mountain habitat (DOE, 1979b).

In the desert regions, the destruction of habitat is primarily due to diversion of water for irrigation, thereby eliminating watering and nesting areas (in particular, wetlands); channelization, which destroys bank vegetation and nesting sites; and construction of conduit facilities, which block migration routes.

In Hawaii, the profound threat to native species from exotic (introduced) species has lead to the rarity, endangerment and extinction of more species of plants, birds, and terrestrial invertebrates than any other state or comparable place on earth. Other major causes include urbanization, forestry, ranching, pineapple, and sugarcane agriculture.

Some habitat loss can be mitigated though techniques that are being improved all the time. Nesting structures for birds can be built to compensate for the lack of natural nesting sites, and nesting islands in streams can be formed by using dredge spoils, as in Topcock Marsh, Arizona, where islands provide habitat for the endangered Yuna clapper rail (U.S.Fish and Wildlife Service, 1978a). On Heron Island in Lake Havasu, Arizona, platforms are being built to protect nesting herons from fishermen and other recreationists (U.S. Fish and Wildlife Service, 1978a).

5. Land Use and Recreation

a. Description

The extent of federal land ownerships or control is a key to land use throughout the region, and in the western United States as a whole. Most land in Arizona and Nevada is controlled by the Bureau of Land Management, other federal agencies, or by Indian Reservations. More than 40 percent of California's land is under the jurisdiction of federal agencies, including such national forests as Plumas, Tahoe, El Dorado, Sierra, and Stanislaus. In Nevada and Arizona, the major national forests or national parks are the Toiyabe and Humboldt in Nevada and the Conconino, Sitgreaves, Tonto and Prescott in Arizona, in addition to the Kofu Game Range near the Gila River and the Imperial National Wildflife Preserve on the Colorado River. The Colorado and its surroundings lie within designated national parks or recreation areas for nearly the river's entire length through Arizona and along the border that the river forms with neighboring Nevada.

Federal wild and scenic rivers in California include the Feather and the American North Fork. The Verde and Salt Rivers in Arizona, as well as the Tuolumne and Kern Rivers in California, are under study for wild and scenic designation (U.S. Department of Interior, 1979). California state wild and scenic rivers are numerous and include all or portions of the Klamath, Scott, Salmon, Wooley, Trinity, Smith Eel and American Rivers. In addition, California has a number of state-protected waterways from which hydroelectric plants are excluded.

b. Issues

Most land-use impacts associated with hydropower development will occur in California along the western flanks of the Sierra. Competition will involve conflicts in particular with recreational uses of water resources, especially white-water and wilderness recreation. Some projects, by the nature of their locations, will displace homes and businesses, as well as some roads and bridges.

Because of the extensive federal landholdings in the region, coordination by applicants with government agencies, particularly the U.S. Forest Service, is a critical component of hydroelectric licensing procedures. In addition, land-use issues will involve transmission line rights-of-way where visual impacts can affect recreational use areas. Transmission line routing is an important issue in Nevada; centering on direct impacts to wilderness or potential wilderness areas or associated with scenic resources. If new facilities are expansions of existing facilities, impacts will be reduced.

The major environmental issue relating to hydropower development in Hawaii will be to avoid impacts to other beneficial stream uses. Hydropower development that minimizes impoundment facilities, operates run of river, minimizes loss of streamflow, avoids blocking the migration of Hawaii's native diadromous stream fauna, minimizes channelization, and retains sufficient water for downstream uses (wet agriculture, aesthetics, fisheries, aquaculture, recreation, irrigation, etc.) will be more favorably received than hydropower development that may exacerbate these effects.

D. Rocky Mountain Region

1. Overview

The four-state Rocky Mountain region, as defined in this study, includes the states of Wyoming, Colorado, Utah, and New Mexico.

Hydroelectric power accounts for approximately 14 percent of the region's power production. Most of the generating capacity consists of conventional hydroelectric projection located at such federal projects as Flaming Gorge, Curecanti, and Lake Powell. Public Service Company of Colorado also operates a pumped storage facility with a capacity of 162 MW at Cabin Creek near Denver. The contribution of hydroelectric generation as a percentage of overall power production is expected to decline within the region, as utilities continue to rely increasingly on coal-fired generation plants and other sources. Nevertheless, additional hydroelectric capacity is projected to be developed in colorado, Utah, and Wyoming. Total electricity capacity within the region is projected to increase from 7,677 MW in 1975 to 16,123 MW in 1990 (DOE, 1979b). These statistics suggest that increased hydropower production would find a market within the region if suitable sites could be developed at competitive costs.

2. Water Quality and Use

a. Description

The major drainage basins within the region are the Missouri, Colorado, Arkansas, Rio Grande and Columbia Rivers. All originate within the Rocky Mountain Province and flow into the more arid, adjacent provinces. All major rivers within the region are characterized by high spring flows, followed by relatively low base flows for the remainder of the year. On many rivers, nearly 70 percent of the annual flow is in May and June, when the rate of snowmelt is highest.

Flow patterns in the region are also characterized by strong variations from year to year. Hydroelectric developments within the region, therefore, have generally had to incorporate storage reservoirs, which must be drawn down during periods of low flow to maintain reliability and generation efficiency. The primary purpose for developing water resources has been to supply water for domestic and agricultural needs. Hydropower represents a minor component of the total development.

b. Issues

The construction of reservoirs has reduced suspended sediment concentrations in a number of rivers within the region. On the Colorado River, for example, the average annual suspended sediment concentration at Lee Ferry has been reduced from about 6,000 ppm to less than 100 ppm (DOE, 1979b). The reduced turbidity coupled with fluctuating streamflow increased erosion below the dam, destabilized rapids (Graf, 1980), removed bed and bank material, and shifted sand bars and beaches.

Because so much of the annual flow of the region's rivers and streams takes place during just two months, many storage reservoirs have been constructed to even out flow. Even so, competition for water is high, and new sources are seldom available unless additional storage facilities are built. Agricultural uses currently consume approximately 90 percent of the region's water. The loss of water by evaporation is a serious concern associated with development of additional storage capacity in the region.

3. Aquatic Ecology

a. Description

The coldwater fishery is typically limited to the mountainous areas, with a mixed-to-warmwater fishery in streams on the plains. At higher elevations, cutthroat trout and mountain whitefish are the only native species. Those natives, particularly the Colorado River and greenback cutthroat, have been largely replaced by introduced species such as the rainbow trout. Other introduced game species include brown trout, brook trout, Yellowstone cutthroat trout, and arctic grayling. At lower elevations, characteristic nongame fish are carp, Utah chub, roundtail, leatherside chub, redside shiner, speckled dace, fathead minnow, flannelmouth sucker, and mottled sculpin. Introduced warmwater game species include channel catfish, black bullhead, and yellow perch. There are essentially no commercial fisheries within the region.

b. Issues

Three endangered species of fish occur within the Colorado River drainage. They include the bonytail and humpback chub and the Colorado squawfish. They are believed to have become endangered by the construction of dams and reservoirs, which has lowered water temperatures and inundated some of the swift river habitat that they require. The occurrence of these species in the Colorado, Yampa, and Green rivers represents potential constraints to further hydroelectric development on those rivers.

Other endangered fish species in the region are the greenback cutthroat trout, woodfin, and Kendall Warm Springs dace. They occur in restricted habitats and are not likely to represent a significant constraint to future hydroelectric development.

Instream flow for fish and aesthetics is a growing issue in the region. States are currently wrestling with ways to ensure flows for fish maintenance while still meeting industrial, agricultural and residential demands for water. An associated issue is the loss of cold water fishing--of particular concern to sportsmen.

4. Terrestrial Ecology

a. Description

Wildlife within the region are those that inhabit the forests of the mountains and the cold deserts. In general, cold-desert communities live on the lower-elevation basin floors, woodland-brushland communities are found on the lower slopes and intermediate plateaus, and the coniferous forest communities are present on the higher plateaus and mountain areas.

The Rocky Mountain region supports some of the largest herds of big-game animals in the nation. Herds of antelope roam the plains; especially in Wyoming. The streams and river fringes on the plains support some white-tail deer, contribute to mule deer populations, and are important winter habitats for sharp-tailed grouse and a host of small animals. The upper plains are also the home of a major part of North America's sage grouse population.

Many species living within the forest, such as mule deer and elk, have marked seasonal cycles and commonly migrate to lower elevations in winter. The numbers of deer and elk are usually restricted by the availability of winter range, which constitutes only a small percentage of the total available habitat.

Endangered mammals within the region include the black-footed ferret, the Utah prairie dog, and the gray wolf. The grizzly bear is a threatened species that inhabits Wyoming and possibly southwestern Colorado. Endangered birds in the region include the American peregrine falcon, arctic peregrine falcon, bald eagle, whooping crane, Mexican duck, and thick-billed parrot. The Eskimo curlew is a threatened species that formerly migrated through the Great Plains portion of the region, but has not been observed there for many years.

Ten species of endangered plants occur within the region. Most are cacti in Western Colorado, Utah, and New Mexico.

b. Issues

Winter range for deer and elk typically includes the lower slopes of the mountains and the adjoining valley fringes between the deep snow at high elevations and the edges of farms and ranches in the valleys. Those are the areas most often affected by water resource/hydroelectric projects; this tends to increase the controversy associated with project development and may require extensive mitigation, such as the acquisition of suitable replacement habitat.

In the cold-desert biome and other arid areas within the region, the narrow belts of riparian vegetation are vital to many wildlife and support a greater diversity of wildlife than any other habitat type. Inundation usually destroys such habitat, which is difficult to reestablish along the reservoir edges in peaking facilities because of fluctuations in water level.

Threatened and endangered species represent a potential constraint to some projects that are located within sensitive habitats. The distribution of these species, however is insufficient to constitute a major constraint to increased hydroelectric development.

5. Land Use and Recreation

a. Description

Land use within the region is primarily agricultural. Approximately 85 to 90 percent of the land within the region is used for some type of agricultural production. Grazing on native range accounts for approximately 70 percent of total land use, and cultivated croplands represent approximately 20 percent (Missouri Basin Interagency Committee, 1971). Much of the region's important agricultural lands lie along rivers and streams because of the relative ease of irrigating such lands, together with the occurrence of generally more favorable soil conditions.

Approximately 260 million acres, or 44 percent of the study area's land, is federally owned. A lower percentage of federally owned land sits along the region's major rivers, because of the higher productivity of such lands and because of their associated attractiveness to homesteaders. Approximately 4,209,000 acres of wilderness have been established on federal lands within the region, mostly in national forests. These areas are unavailable for hydroelectric development, and some potential sites have been precluded by their establishment. An additional 3,583,540 acres have been proposed for wilderness through the RARE II Process (DOE, 1979b).

In mountainous and wooded areas of the region, recreation is an important industry that provides both income and employment to rural communities. The region contains some of the nation's most popular rivers for float trips. For example, boating on the Green and Yampa Rivers through Dinosaur National Monument totals 60,000 user-days per year. Another 30,000 user-days are recorded on the Green River in Utah through Gray and Desolation Canyons. Both visitation levels would probably be higher if agencies had not imposed ceilings on use. Other popular rivers include segments of the Green in Wyoming, the Colorado in Utah and Colorado, the Snake in Wyoming, the North Platte in Colorado and Wyoming, the Dolores in Colorado, and the Rio Grande in New Mexico. Many other rivers, such as the Roaring Fork and the Cache la Poudre in Colorado, are of regional significance to river recreationists.

b. Issues

Loss of wilderness character and free-flowing rivers from water resource projects and construction of transmission lines is an important land-use issue. The region contains some of the nation's outstanding recreational resources, including 27 national parks and monuments, 30 national forests, four national recreation areas and numerous areas on Bureau of Land Management, state, and privately-owned lands that offer exceptional recreational opportunities. A growing recreational attraction is the natural mountainous setting as a place for hiking and backpacking. Hydroelectric development has influenced recreational opportunities within the region in two primary ways: (1) storage reservoirs (used primarily for water supply) have been constructed, providing opportunities for reservoir-based recreational activities; and (2) river-based recreation activities have been lost or modified by inundation and flow regulation.

One river in the region has been included within the National Wild and Scenic River system: a 52.75-mile segment of the Rio Grande in northern New Mexico. Several other rivers, however, have been recommended or are being studied for inclusion within the system. They include portions of the Cache la Poudre, Yampa, Green, Dolores, Encampment, Gunnison, Los Pinos, Piedra, and Colorado Rivers in Colorado, Clark's Fork of the Yellowstone and the Snake Rivers in Wyoming, and the Green River in Eastern Utah. Hydroelectric development would be precluded on those portions of any river that are included within the wild and scenic river system.

Construction of hydroelectric projects can eliminate river boating opportunities through inundation, and can affect a much larger portion of the basin by reducing peak flows and scheduling irregular releases. Although reservoir releases can be scheduled to benefit river boating by extending the season into late summer and fall, the development of hydroelectric projects is generally viewed as posing a conflict with river boating.

E. Plains Region

1. Overview

The nine-state Plains Regions as defined in this study includes North Dakota, South Dakota, Minnesota, Nebraska, Iowa, Kansas, Missouri, Oklahoma, and Texas.

Most of the region lies within the Great Plains and Central Lowland physiographic provinces, which are characterized by a lack of topographic relief that results in relatively shallow storage reservoirs that occupy a large land area. Deeper, confined storage sites are available only in the Black Hills of South Dakota and the Ozark Plateau and Quachita Mountain Provinces in Missouri and Oklahoma.

Hydroelectric generation accounts for approximately 5 percent of the region's power production. Only in the Dakotas, where large federal projects have been constructed on the Missouri River, does hydropower represent a significant percentage of total generation capacity. The contribution of hydroelectric generation as a percentage of overall power production is expected to decline as utilities continue to rely increasingly on coal-fired facilities. Although total electricity production within the region is projected to increase from 83,828 MW in 1975 to 161,180 in 1990, less than 1 percent of the total increase is projected to be provided by hydropower (DOE, 1979b).

2. Water Quality and Use

a. Description

Streamflow patterns are highly variable. In the Souris-Red-Rainey River drainages in North Dakota and Minnesota, as much as 80 percent of the total annual flow takes place in April. Peak flows in the western plains portion of the region, with the exception of the regulated Missouri mainstream, take place in late spring, with approximately 25 percent of the total annual flow coming in June. Peak flows in the remainder of the region take place in winter and early spring, and display a somewhat more even flow pattern than rivers in the northern and western portions of the region (Hunt, 1967).

Several major rivers within the region are navigable and serve as important transportation corridors. The Upper Mississippi River Basin contains over 1,250 miles of waterways improved for commercial navigation. The Mississippi River is navigable throughout the study area except for the upper reaches above Minneapolis, Minnesota. The Missouri River is navigable from its confluence with the Mississippi to Sioux City, Iowa. The lower few miles of the Kansas River are being improved for navigation. Other potentially navigable rivers include the lower 21 miles of the Meramec in Missouri and the Minnesota River above Savage to LeSuer, Minnesota. Many rivers along the Texas coast are navigable for a short distance inland.

b. Issues

Competition for water is high in the more arid, western portions of the region. Shortages already exist for irrigation water along the Platte River in Nebraska. Localized water supplies have also been short along the Des Moines and Cedar Rivers in Iowa. Water shortages are also projected in the Texas-Gulf, Lower Arkansas-Red and Colorado (Texas) River Basins (DOE, 1979b). However, the creation of a reservoir for hydroelectric generation could provide a water supply as an added benefit of the development.

Sediment loads have been greatly reduced on the Missouri River by the construction of several major dams, each acting as a sediment trap. Reservoirs on other drainages in the region that currently carry heavy loads of suspended solids could produce a similar reduction. Although the decreased turbidity is considered a benefit in the Missouri River basin, the increased erosion downstream of each dam changes the morphology of the stream and that region's navigable rivers may create conflicts by altering flow patterns and presenting structural obstacles. In fact, fluctuations in downstream water levels are a major adverse impact of such development.

3. Aquatic Ecology

a. Description

Most rivers within the region support a warmwater fishery. Typical species include catfish, carp, bullhead yellow perch, bluegills, largemouth bass, crappie, shiners and minnows. The fountain darter, which occurs in Texas, is the only endangered fish species present within the region. However, the pallid sturgeon occupies the upper Missouri River, and has been recommended for inclusion as an endangered species as is the shovelnose sturgeon (Corps, 1978).

Of special interest is the paddlefish, found throughout the Missouri River drainage basin. The paddlefish is one of the world's oldest living species of fish, and is believed to be declining, probably for a lack of suitable spawning areas. Many spawning areas have been lost to improvements in navigation and water storage projects (Corps, 1978).

Commercial fisheries within the region are largely limited to the Mississippi River and Lake Superior. The Upper Mississippi supports an important commercial fishery, consisting of carp, buffalofish, catfish, bullhead and sheepshead. Commercial fishermen also fish the St. Croix River in Minnesota (Upper Mississippi River Basin Coordinating Committee, 1972). Some commercial fishing operations continue on the Missouri River and all of the Missouri main stem reservoirs, except Gavins Point.

b. Issues

Mortality and entrapment in turbines and the loss of spawning beds are major concerns on the Missouri River. In the tailwaters of deeper riverbed streams, fish could be adversely affected by gas supersaturation. Releases from large reservoirs on the Missouri River are colder than would exist in a free-flowing river. The construction of reregulating structures downstream of reservoirs such as Garrison and Lake Francis Case would allow increased hydroelectric production and also warm the water downstream and encourage an increased relative abundance of fish species (Corps, 1978). However, upstream from the reregulation structures, the river will become an impoundment with greatly fluctuating water levels. This change will alter vegetation along the banks and result in some fishery loss.

4. Terrestrial Ecology

a. Description

Wildlife typical of prairie and agricultural lands are found within the region. Included are whitetail deer, eastern cottontail, red fox, and coyote. The bald eagle winters along the Missouri River south from Lake Sakakawea, but the largest concentrations are found at the Karl E. Mundt National Wildlife Refuge below Fort Randall Dam, where as many as 200 eagles congregate from November to February (Corps, 1978).

Important habitat for the whooping crane is present along the Platte River in Nebraska and to a lesser extent along the Missouri River in the Dakotas.

The region contains 14 endangered species, including the red wolf, gray wolf, Indiana bat, gray bat, Ozark big-eared bat, peregrine falcon, Eskimo curlew, bald eagle, red-cockaded woodpecker, Bachman's warbler, black-footed ferret, whooping crane, Houston toad, and Mexican duck.

Endangered plant species include Texas wild rice and northern wild monkshood. Four species of endangered plants are present in Missouri.

b. Issues

In most of the prairie portions of the region, floodplain forests along major rivers are particularly important wildlife habitats. The remaining cottonwood-dominated, high-bank woodland is a unique and irreplaceable habitat (Corps, 1978). Inundation or alteration of this riparian habitat in association with hydropower development would constitute a significant tradeoff. The large number of endangered species within the region also represents a potential constraint to large-scale hydropower development.

5. Land Use and Recreation

a. Description

Land use within the region is predominantly agricultural. The region contains some of the most productive agricultural lands in the Untied States, and is the nation's major producer of wheat and corn. In the western portion of the region, some of the most valuable agricultural lands are located along major rivers, where better soils and ease of irrigation make cultivation more practical. Upland areas in the western portions of the region are used predominantly for livestock grazing on native range. The lack of relief and more humid conditions in the eastern portion of the region tend to diminish the special significance of river bottomlands for agricultural use.

Extensive woodlands are located in Northern Minnesota, Southwest Missouri and Eastern Oklahoma, and East Texas.

Federal ownership constitutes a small percentage of total land ownership within the region. Wilderness areas, except for the boundary waters canoe area in Northern Minnesota, consist of small, scattered tracts.

Designated national wild and scenic rivers within the region include a 58-mile segment of the Missouri from Gavins Point, South Dakota, to Ponca State Park, Nebraska, a 52-mile segment of the St. Croix in Minnesota, a 44-mile segment of the Eleven Point and the Upper Current in Missouri, and a 191-mile segment of the Rio Grande in Texas. Potential additions to the system include portions of the Illinois in eastern Oklahoma, the Gasconade in Missouri, the Upper Iowa in Iowa, the Upper Mississippi and Kettle in Minnesota, the Cimmarron in Kansas and Oklahoma, the Colorado and Pease in Texas, and the Kiamichi, Blue, and Mountain Fork Rivers in Oklahoma. Several rivers have been designated state wild and scenic rivers, including portions of the Mountain Fork and La Creek in eastern Oklahoma, the Little Missouri in North Dakota, and the north fork of the Crow in Minnesota.

b. Issues

The creation of reservoirs at the expense of productive agricultural land is a major concern in the region. However, in many parts of the region, agricultural development is greatly enhanced by the availability of an assured water supply throughout the year--an accomplishment made possible by the extensive development of storage reservoirs. In the southern states, reservoirs provide necessary flood protection and, in fact, allow year-round farming of bottomlands, which previously were often flooded for several months of every year. Although the development of new sites would require an assessment of these tradeoffs, the addition of hydropower to an existing dam should not substantially affect present land uses.

Two additional land-use issues in the region are the loss of a navigation route and the infringement on wild and scenic rivers. The Mississippi and lower Missouri Rivers support considerable navigation. Existing federal laws will prevent any hydropower development that would impede navigation. At the same time navigation dams, in some cases, can be retrofitted with hydropower turbines. Because many of the larger rivers in the region have been thoroughly developed by man, designated and proposed wild and scenic rivers are highly valued. Hydroelectric development that affects such resources will meet substantial opposition.

F. Central Region

1. Overview

The Central region includes the states of Wisconsin, Illinois, Michigan, Indiana, Kentucky, Ohio, West Virginia, and Pennsylvania. The Central Lowland Province occupies most of the region, and is flat to slightly rolling, with low river gradients and few sites for deep storage reservoirs. All of the other provinces are characterized by uplands with rolling to rugged topography and numerous sites for deep, confined storage facilities.

Hydroelectric power accounts for less than 5 percent of the region's power production (DOE, 1979). The region currently produces approximately 70 percent of the nation's bituminous coal, and thus relies heavily on coal-fired, thermal electric facilities. The Ohio River Basin currently has 1,400 MW of hydropower facilities and potential for substantial additional capacity. Most potential sites are either at existing dams or at sites in the Appalachian Plateau where sufficiently high dams could be built (Ohio River Basin Commission, 1978). The potential for additional conventional hydropower and pumped storage is projected for development in eastern Pennyslvania, Michigan, and Wisconsin (Corps, 1980b and DOE, 1979b). However, hydropower represents only a small percentage of the total increased electric capacity that is projected for the region (DOE, 1979).

2. Water Quality and Use

a. Description

Historically, water availability has not been a major problem within the region. The Great Lakes, and the Mississippi, Ohio, Illinois, and Wabash Rivers provide an abundant supply.

Because of the region's abundant precipitation, agricultural water use is low. Industrial use, including thermal power generation, is by far the largest use, followed by municipal and then agricultural uses (Ohio River Basin Commission, 1978). Along some tributaries, however, many of the smaller watersheds have extremely low seasonal flows and cannot support local water demand. They often require flow augmentation during part of the year.

The region's rivers are by far the most important inland waterways for commercial navigation in the nation. The Mississippi River, which forms the western boundary of the region, carries the most river freight in the nation. The Ohio River carries the second largest volume of traffic. It has been channelized by a system of locks and dams from Pittsburgh to the Mississippi River, and carried 148 million tons of freight in 1976. Many tributaries to the Ohio River and other rivers are also navigable. Navigable tributaries include the Monongahela, Allegheny, Kanawa, Kentucky, Green, Cumberland, and Kaskaskia Rivers.

Flooding is a considerable problem in this region. Nearly all of the existing storage reservoirs were constructed with flood protection as their primary purpose. Recent major floods may indicate the need for additional protection.

b. Issues

The high level of nutrients and other pollutants in many of the region's rivers increases the possibility of eutrophication and other water quality problems in reservoirs constructed in association with hydropower projects. A release of water from the hypolimnion during periods of stratification that contain low concentrations of dissolved oxygen can kill fish or significantly alter the distribution of fish by increasing the relative abundance of less desirable sport fishing species such as carp.

The addition of hydropower to existing dams would require coordination with flood-control projects to ensure maximum protection to downstream residents.

3. Aquatic Ecology

a. Description

The region's abundant water bodies support more than 300 species of fish. Fisheries are about equally divided between warmwater and coldwater species. Coldwater species inhabit the northern and Appalachian Upland portions of the region. Popular game fish include largemouth and smallmouth bass, brook, brown and rainbow trout, bluegill, crappie, northern pike, catfish, yellow perch, white bass, and yellow bass. In the Great Lakes, Pacific salmon were recently introduced as part of a program to restore migratory fish to the region. They spend their adult lives in the Great Lakes and travel into the tributaries of these lakes to spawn. The Scioto madtom is the only endangered fish species in the region. Its distribution is limited to Central Ohio, and it may already be extinct.

Nine species of endangered mussels occur within the major rivers of the area. They have become endangered because their habitats have been destroyed by pollution and siltation.

The Great Lakes contain a major commercial fishery. It probably will not be significantly affected by hydropower development. Only minor commercial fishing takes place within the region's major rivers, except on the Mississippi River, which is described in the profile of the Plains Region.

The Delaware and Susquehanna Rivers are fished commercially for anadromous species such as shad, of which an average of 275,000 pounds are harvested each year from the Delaware. Other anadromous species present in smaller numbers are striped bass, herring, and white perch. Eel, a catadromous species, is also present and is still harvested commercially in the Delaware River, particularly in the upland areas of the drainage basin (Corps, 1970).

b. Issues

Projects constructed on the region's major rivers such as the Delaware and Susquehanna, where anadromous and catadromous species are present, would probably have to provide fish passage structures. Even with such structures, the species would probably be adversely affected by the construction of dams and reservoirs (Corps, 1980b).

The possible loss of spawning beds from hydropower development is of major concern in this region. For example, streams entering the Great Lakes provide spawning habitat for a number of fish species. Such habitats are generally numerous in the region, but hydropower facilities would have to be sited with an awareness of the location of important spawning areas (Great Lakes Basin Commission, 1976). Changes in water levels both in the reservoir and downstream affect not only spawning habitat, but may also threaten critical habitat of endangered species--an additional concern in the region.

4. Terrestrial Ecology

a. Description

The agricultural lands and forests of the regions provide habitat for several species. Typical forest mammals include whitetail deer, black bear, woodchuck, and gray fox. Species typical of the farm areas and forest edge include whitetail deer, red fox, and coyote. Furbearers, such as mink, beaver, and muskrat, live along waterways and in marshy habitats. The Indiana bat is the most widely distributed endangered species within the region, and inhabits all eight states. Other endangered species include the gray wolf in northern Michigan and Wisconsin, the peregrine falcon, Kirtland's warbler, and the gray bat. The bald eagle is another threatened species within the region.

Wetlands along some of the region's major rivers are important wildlife habitats. An estimated 2.3 percent of the Ohio River floodplain of 846,700 acres is wetlands that should be preserved from encroachment (Ohio River Basin Commission, 1978).

b. Issues

In general, bottomlands along major rivers in the region lack the unique habitat value that such lands have in more arid, less forested regions. The value of floodplain habitats in many areas has also been diminished by urban, industrial, and agricultural development.

Displacement of indigenous wildlife and loss of endangered species as a result of development of new reservoirs are major concerns in the region. As described, riparian habitat supports abundant wildlife as an integral part of the food chain. The loss or degradation of wetlands is of particular concern. Research efforts have focused on this problem and attendant degradation in waterfowl populations and migration as well as water quality.

5. Land Use and Recreation

a. Description

Land-use patterns vary substantially across the region. The northern portions of Wisconsin and Michigan are primarily forested. Land use in the southern portions of these states is predominantly agricultural, a pattern that extends into Indiana, Illinois, and Ohio.

Land ownership is predominantly private, but some areas of national forest are present in northern Michigan and Wisconsin, in Southern Illinois, Indiana and Ohio, Eastern West Virginia, and Northwestern Pennsylvania. Only a few small areas of wilderness have been preserved in the region's national forests.

Most areas in the Ohio River Basin have inadequate facilities to meet needs for surface water boating and fishing. Needs are greatest north of the Ohio River, where the larger population centers are located (Ohio River Basin Commission, 1978).

Several rivers within the region have been included within the national wild and scenic river system. Such rivers include the St. Croix and Wolf in Wisconsin and the Little Miami and Little Beaver Creek in Ohio. Portions of several additional rivers within the region have been proposed for inclusion within the system, including the Wisconsin, Au Sable, Manistee, Pere Marquette, Youghiogheny, Pine Creek, and Delaware. In addition, many more rivers have been included or proposed for inclusion within state wild and scenic river systems, particularly in Ohio, Michigan, West Virginia, and Pennyslvania.

b. Issues

Because this region is well-populated, dotted with small towns and agricultural areas, the development of reservoirs often creates significant conflict with impacted residents. In addition, conversion of agriculturally rich bottomland to reservoir storage is sometimes considered a major cost of development and is viewed unfavorably by local interest groups.

Although the increased opportunity for flat-water recreation is a benefit to some portions of the region, the development of new reservoirs is more often considered to degrade recreational opportunities--in particular, white-water canoeing and kayacking, and sport fishing.

G. North Atlantic Region

1. Overview

The eight-state North Atlantic Region includes the six New England states of Maine, New Hampshire, Vermont, Massachusetts, Connecticut and Rhode Island, plus New York and New Jersey.

In 1979, hydroelectric power accounted for approximately 15 percent of Northeast Power Council production. This figure represent an increase of one to two percent from 1977-78 (National Electric Reliability Council, 1978 and

1979). Existing hydropower sites will probably be redeveloped to help meet projected energy demands. Of the 10,000 or so existing dams in New England alone, nearly 2,000 have the capability, if repaired and equipped properly, to produce an additional 1,800 megawatts of electricity (New England River Basins Commission, 1980). As of January 1980, the Northeast Power Council, which supplies 98 percent of the electricity consumed in New England and New York, had a hydro-generating potential of nearly 8,000 MW. In addition, small unreported plants are estimated to have a 461-MW capacity. The full potential represents about eight percent of the region's current total power needs and about 15 percent of the additional power needed during the next 10 years (New England River Basins Commission, 1980). Those figures will likely shrink after economic and environmental constraints are considered.

About 90 percent of all existing hydropower facilities in the Northeast are run-of-river; 10 percent are conventional storage facilities. Private investors own practically all of New England's hydropower capability; in New York, 20 percent belonged to investors in 1977 with the State owning the remaining 80 percent.

2. Water Quality and Use

a. Description

Within the last decade, much has been done to improve water quality by treating the major point sources--industrial and municipal wastewater. Nonpoint source pollution is more difficult to control, and its contribution to water quality problems has been overshadowed by the more significant point sources. Typical nonpoint sources include malfunctioning subsurface waste disposal systems, stormwater runoff, erosion and sedimentation, agricultural runoff, road salt, and residues from boating and from forestry operations.

Despite efforts to improve water quality, many of the major rivers have sections that are still seriously polluted eutrophication stemming from both point discharges and nonpoint source pollution is also widespread. Excessive blooms of algae during the recreational season hamper swimming. Water quality has been dramatically improved in other river sections. Increased water quality has generated increased recreational demands and also renewed interest in anadromous fisheries.

b. Issues

Flooding in the region occurs during the late winter months, owing to heavy rains and snowmelt. Losses from flooding are considerable, perhaps second only to those in the Central region. Therefore, hydropower operation would have to be coordinated with flood control.

Many existing dams have received high hazard potential ratings from the Corps. For hydroelectric facility licensing, the FERC requires that dams and other related structures be sound. Thus, retrofitting of existing dams for hydroelectric power may require major structural improvements.

Many dams and powerhouses are listed in the Federal Register as historic sites, and thus may be in conflict with hydroelectric development (DOE, 1979). Additionally, dredging behind existing dams and deposition of the spoils, with potential for increased reservoir siltation, are two construction activities that may affect the development of hydropower (Loar et. al., 1979).

Water pollution is a major issue because of industrial, municipal (sewage), and nonpoint source discharges. Some streams and rivers contain high levels of organic materials, toxic substances, suspended solids, and dissolved minerals. Dissolved oxygen levels are often below levels necessary to support aquatic life; in addition, water temperatures are often elevated. The potential for rapid eutrophication of newly-constructed reservoirs is considerable. In addition, reservoir stratification and release of severely degraded water can also adversely affect downstream habitats and water users.

Renewed interest in anadromous fisheries in the Merrimack, Kennebec, and Piscataqua rivers, for example, could also pose a conflict with hydropower development because of potential problems with water flow and quality (New England River Basins Commission, 1978, 1979a, 1979b, 1980b).

3. Aquatic Ecology

a. Description

Both warmwater and coldwater fish species inhabit the region's waterways. Important resident coldwater species are rainbow, brook, lake, and brown trout, and landlocked salmon. Trout are artificially stocked in many areas where waters are too warm and too low in dissolved oxygen to support natural populations. Major warmwater fishes, which are restricted mainly to the central and southern parts of the region, include largemouth and smallmouth bass, northern pike, sunfish, perch, crappie, walleye, chain pickerel, and muskellunge. The endangered shortnose sturgeon is also found in the area.

Anadramous fish include striped bass, American shad, white perch, smelt, alewives, blueback herring, Atlantic salmon, and sea-run brown trout. They are important both as sport and commercial species. Anadromous fish once thrived in the region, but recently have suffered from pollution, over-harvesting, and the construction of dams, which has prevented fish from reaching historic spawning and nursery areas. In addition, dams have changed areas of quick water and natural falls into long, deep impoundments; thus, shallow riffle areas vital to spawning and nursery activities have been lost. Atlantic salmon, although not listted as an endangered species, are the object of a restoration program that, in terms of funds allocated by state and federal governments, is probably second only to that for the whooping crane. The success of restoration programs for salmon and shad species has yet to be proven.

The estuaries support large fish and shellfish fisheries, and also provide important rearing areas for many anadromous fish species. Shellfish include shrimp, oysters, and crab. The commercial catch of edible fish, shellfish and industrial fish in the region amounts to hundreds of thousands of dollars annually.

b. Issues

Restoration of anadromous fisheries in New England rivers is a central issue in the relicensing of existing hydropower plants. The provision of fish passageways for all dams (whether for hydropower or not) on rivers that have anadromous fish and the maintenance of instream flow are all limiting criteria. However, the Maine Department of Inland Fisheries and Wildlife states that the installation of fish passage facilities would introduce undesirable species into upstream waters, result in habitat competition among coldwater species, and prove uneconomical (New England River Basins Commission, 1980).

Hydroelectric facilities may alter streamflow characteristics, affecting fish habitat, spawning beds, assimilative capacity, and the availability of water for public supply systems. Provisions for maintaining minimum instantaneous flow along rivers that create hydropower could mitigate many adverse effects, although the extent of the efforts would depend on the mode of operation (peaking or base) and the type of technology designed for each particular installation. At present, the U.S. Fish and Wildlife Service in New England determines the minimum streamflow required below hydropower facilities to mitigate adverse effects. Recently, the Service proposed a policy that hydroelectric producers must provide a fish maintenance flow equal to 0.5 cubic feet per second per square mile of drainage area above the dam during summer months.

4. Terrestrial Ecology

a. Description

The river and estuaries of the region provide resting and feeding areas for waterfowl that use the Atlantic flyway. Some nesting occurs there also. Waterfowl commonly observed in the area are Canada geese, brant, scaups, scoters, blackduck, mallard, canvasback, and eiders. Riverine habitats of the region provide important nesting areas for wood duck. Beaver, mink, muskrat, and other species of fur animals also use the waters.

Open land and young forest stands provide favorable habitat for white-tailed deer, rabbits, and squirrels. Pheasant and wild turkey can be found in selected areas. The endangered bald eagle is known to nest in the lower Kennebec River Basin.

State wildlife management efforts center on the maintenance of game populations through monitoring, harvest regulation, and habitat preservation. In addition, enhancement of non-game species of wildlife that depend on wetlands and other habitat, and the protection of rare and endangered species are objectives of managerial efforts. An active pheasant-stocking program is being conducted in New Hampshire, and wild turkeys are being introduced in Maine (New England River Basins Commission, 1980). Various private conservation groups also maintain wildlife sanctuaries in the river basin.

b. Issues

The loss of habitat to urban development, particularly in the faster-growing southern and coastal portions of the study area, is the primary constraint on wildlife.

In most cases, existing dams that have reservoirs would not be greatly increased in size by the addition of hydropower facilities. Retrofitting would, therefore, have little effect on existing ecosystems that have already stabilized around the dams and now depend on them.

Construction of big projects with large reservoirs is another matter, for they have a major impact on surrounding ecosystems. Property for the project is removed from other uses. Streams in the impounded area are changed from a flowing to a standing water habitat, shifting the makeup of the aquatic ecosystem. In the North Atlantic region, creation or expansion of large reservoirs can cause the following adverse effects: loss of economically important forestry resources, loss of riparian and aquatic habitat, loss of wetlands, threatening of rare and endangered species, displacement of indigenous wildlife and migration patterns, and disturbance of waterfowl nesting areas.

5. Land Use and Recreation

a. Description

Flooding is a major problem, and the pattern of homes, industries, roads, and utility corridors within the floodplains in urban areas aggravates the difficulty by preempting the natural storage function of flood plains.

Wilderness areas in the region are primarily U.S. Forest Service areas-the Green and Mountain National Forests in Vermont and the White Mountain National Forest in New Hampshire (U.S. Department of Interior, 1979). The Adirondack Forest Preserve in Northern New York is an extensive spruce and pine state forest that contains some designated wilderness areas. National Wild and Scenic Rivers include the Allagash (Maine), the upper Delaware (New York/ Pennsylvania border), and the middle Delaware (New Jersey/Pennsylvania border). The Penobscot (Maine), Fish Creek (New York) the Housatonic and the Shepaug (Connecticut) are all under study (U.S. Department of the Interior, 1979). Other rivers are being studied by the Heritage Conservation and Recreation Service (HCRS) as part of its nationwide recreational river inventory.

Key water-based recreational activities are fishing, swimming, boating, canoeing, and related picnicking, camping, hiking, and hunting. Some white-water rafting areas exist in free-flowing Maine rivers, but may be lost if water is impounded for hydropower.

Recreation projections for the North Atlantic region are for 75.9 million person-days of sport fishing and 51.3 million person-days of hunting in 1980, with 99.5 million person-days and sport fishing and 48.3 million person-days of hunting in the year 2000 (Todd, 1970).

b. Issues

The operation of peaking units conflicts with river boating and fishing. Creation of impoundments frequently destroys valuable stretches of white-water. In addition, residents in the North Atlantic region place a high value on the pristine character of the forests in the region. The intrusion by transmission lines or hydropower facilities and impoundments destroys this character. The loss of valuable land for agriculture, timber, or mining is a potentially adverse impact of new development.

H. South Atlantic Region

1. Overview

The South Atlantic region contains 12 states: Arkansas, Louisiana, Tennessee, Mississippi, Alabama, Georgia, Florida, South Carolina, North Carolina, Virginia, Maryland, and Delaware.

Hydroelectric power provides approximately 10 percent of the region's power.

The "Fall Line" extends from Northeast Mississippi to the northern border of the region at the Delaware state line and divides the Coastal Plain from the Piedmont plateau. It is characterized by a band of resistant bedrock that often causes waterfalls or rapids in rivers that discharge into the Coastal Plain. Hydropower projects in the Coastal Plain generally operate on a run-of-river basis. Hydropower plants located above the "Fall Line" in the Piedmont and mountain areas are most often constructed as peaking units. Pumped-storage units are built in steep terrain to compensate for the limited storage capacity of the reservoirs (Corps, 1980a).

The TVA operates major dam projects along the Tennessee River, the largest being the Wilson Dam (629 MW) and the Wheeler Dam (356 MW). Private utility companies, taken as a group, constitute the region's second major producer of hydroelectric energy. The Conowingo Dam in Maryland is operated by the Philadelphia Electric and Susquehanna Power Company, and generates 474 MW (Corps, 1980a). The Corps of Engineers is the third major producer in the region. The Corps operates Lake Hartwell Dam (264 MW) and is constructing the Richard B. Russell Dam (300 MW estimated).

Major emphasis is now being placed on the restoration and retrofitting of Soil Conservation Service impoundments and of numerous small-scale hydroelectric facilities, particularly abandoned dams from 19th Century textile mills of the Western Carolinas and Northern Georgia.

Louisiana, Mississippi, Florida and Delaware, because of their flat terrain, have no significant hydropower development or potential. Hydroelectric power generation as a percentage of overall power production is expected to decline in the South Atlantic region by 1990 as the region increases its reliance on coal- and gas-fired plants for the generation of electricity.

2. Water Quality and Use

a. Description

Heavily polluted rivers and flood plains in the region, i.e., those with 50 percent or greater polluted stream miles, include the Mississippi, the Red, the Tombigbee, the Coosa, the Chattahoochee, the St. Johns, the Savannah, the Cape Fear, the Roanoke and the Upper Tennessee (Water Resources Council, 1978). Stratification and resulting degradation of water quality have been identified as a major problem in the rivers. Anoxic conditions in the hypolimnion are common during summer and winter.

b. Issues

Extensive hydroelectric development in the region has led to equally extensive effects on water quantity and quality in streams. Fluctuation of water levels below dams is a major adverse effect from hydroelectric development. In addition to alterations in river morphology, secondary impacts on aquatic habitat and riverine ecology are common.

Stratification of reservoirs leads to significant degradation of downstream water quality. Water discharged from the hypolimnion during periods of stratification is depleted in oxygen and enriched in nitrogen, amonia, hydrogen, sulfide, and some heavy metals. The problem is especially intense when several large reservoirs are located nearby in the same watershed. In such cases, downstream reservoirs are unable to assimilate the increased pollutant load and rapidly become eutrophic.

Reservoir construction has decreased concentrations of both suspended sediments and dissolved solids in the rivers of the region. However, dredging operations associated with the refurbishing of existing small hydroelectric plants may possibly increase turbidity and cause siltation downstream (Loar et al., 1979). During periods of low streamflow, both southern Florida and metropolitan Atlanta are projected by 1995 to experience severe water shortages, thereby limiting the supply of water for both urban use and energy consumption. Augmentation of low flow at inland hydroelectric facilities is required by local river commissions in Virginia, Maryland, and Delaware. Because of these constraints in water availability, some proposed dam projects have been abandoned.

3. Aquatic Ecology

a. Description

Endangered and threatened aquatic animals are concentrated in the Appalachian and Cumberland Plateaus and include the snail darter and various mussels and snails (U.S. fish and Wildlife Service, 1980).

The region supports substantial populations of anadromous fish, including white and striped bass, rainbow and brook trout, and shad, which live in the Atlantic Ocean or the Gulf of Mexico and swim up freshwater rivers to spawn. Commercial fish, inhabiting large rivers and reservoirs, are the paddlefish, carp, catfish and buffalofish. Fresh water stream fish, such as the walleye, redeye, and smallmouth bass are considered sport fish.

The building of hydroelectric facilities has adversely affected aquatic life in four basic ways: (1) the amount of dissolved available oxygen has been reduced in both river and reservoir environments, (2) dams have blocked movements of anadromous fish, (3) downstream temperatures have been lowered, and (4) fluctuating water flows have reduced populations of benthic organisms and interfered with the life cycle of fish, particularly during the sensitive egg, larvae, and fingerling states.

b. Issues

The blocking of anadromous fish is a major impact of the development at new sites. The fish will seriously decline unless fish passage is mandated. Retrofitting existing dams with hydropower may be viewed by fish and wildlife personnel as an opportunity to add fish passage and thereby improve fisheries habitat.

The development of new sites has advantages as well as disadvantages in the South Atlantic region. The creation of a new impoundment destroys spawning areas and completely alters the composition of aquatic species.

However, a warmwater fishery--often with higher productivity--replaces the coldwater fishery. If the new sites are operated as peaking facilities, they will cause rapid changes in the volume of water released. As a result, substantial losses in spawning areas and benthos can occur in the reservoir and downstream from the dam.

Fresh water mussels are important members of the South Atlantic riverine habitats, providing food for muskrats, otters, turtles, and fish. Mussels also remove suspended silt from water and collect pollutants within their shells and tissues. Mussels are generally sensitive to environmental changes, and their decline has been brought about by the construction of dams and the pollution of rivers (U.S. Fish and Wildlife Service, 1977-78).

4. Terrestrial Ecology

a. Description

The South Atlantic region supports a greater diversity of plant and animal species than any other region in the Continental United States, in part because of the region's overall high humidity, abundant available ground and surface water, warm temperatures, and the resultant long growing season. The four ecologic provinces in the region are: (1) the Eastern Deciduous forest, (2) the Southeastern Mixed Forest, (3) the Outer Coastal Plain, and (4) the Savannah, i.e., the Everglades of Southern Florida.

Buttonbush, green ash, swamp tupelo, eastern cottonwood, and black willow are woody plants that occur over most of the region and are highly tolerant of fluctuations in moisture regime (U.S. Fish and Wildlife Service, 1977). However, most of the oaks, hickories, walnuts, and pines of the region are intolerant of changes in water level.

b. Issues

Most of the major rivers of the South Atlantic region have either been dammed or channelized. In the Lower Mississippi Valley, this has lead to a significant decline in areas formerly covered in floodplain and bottomland vegetation and occupied by associated wildlife. The five southeastern states (Florida, Georgia, North and South Carolina, and Virginia) have maintained stable acreages during the past four decades. Tree volumes are, in fact, increasing in the 5-state area. The major concerns related to hydropower development in the region include the destruction of riverine habitat; loss of riparian edge, and the displacement or loss of riverine wildlife.

5. Land Use and Recreation

a. Description

Agriculture is the primary land use in the South Atlantic region. The Appalachian Mountains for the most part are wooded and ungrazed. Land in mountain valleys, on the Coastal Plain and in the Piedmont contains cropland and pasture and must woodland and forest. Marshland and swamps line the Atlantic Coast. Bottomland hardwoods parallel the Mississippi River except at its most southern part, where marshes predominate. In Central and southern Florida, land is irrigated extensively. The Appalachian National Scenic Trail runs through Virginia, North Carolina, and Georgia, crossing the Tennessee River in Tennessee and the Roanoke River in Virginia. There are four national parks in the South Atlantic region: Hot springs, Everglades, Great Smokey Mountains, and Shenandoah.

Designated wild and scenic rivers in the region are the Obed in Tennessee, the New River in Virginia and North Carolina, and the Chatooga in North Carolina, Georgia, and South Carolina. The Chatooga is one of the longest free-flowing rivers in the Southeast, and has little significant agricultural, residential, or commercial development along it. The Suwannee River in Florida is up for review for inclusion in the wild and scenic rivers system. Studies on 13 additional rivers in the region are in progress (U.S. Department of Interior, 1979).

Canoeing and rafting are expected to increase on the region's rivers; sailing is becoming increasingly popular at the region's reservoirs. Fishing, camping, and picnicking are common to both lake and river environments.

b. Issues

Because natural lakes in the region are relatively rare, the construction of hydroelectric facilities has offered opportunities for reservoir-based recreation in the region. River-based recreation, however, has been adversely affected. Reservoirs and dams obstruct canoers and rafters. Downstream from peaking units, fluctuating waterflows interfere with river boating and fishing.

Visual intrusion from transmission lines and rights of way is an adverse impact of hydropower development in the region, and results regardless of the size or type of facility constructed.

CHAPTER 5

REGIONAL ENVIRONMENTAL ASSESSMENT

A. Introduction

This chapter presents an overview environmental assessment of the impacts and issues associated with future hydropower development that may arise in different regions of the country. The objective of the assessment is to highlight important concerns and issues that should be addressed in feasibility studies at specific sites.

The chapter begins by presenting a summary of the potential sites that were selected as most suitable for further study in the NHS regional reports. These sites were screened based on physical, economic, and environmental criteria and were selected for further study from over 70,000 potential sites. The sites are categorized according to the characteristics described in Chapter 2. Next, the likely mix of future energy sources for each region is presented. This information is used to better understand the implication of a decision to develop or not develop hydropower resources. Finally, an environmental assessment is presented for each region.

B. Projected Regional Development

1. Hydropower Projections

The regional distribution of potential hydropower sites is heavily skewed. By far, the largest portion of the United States does not have the topographic and hydrologic characteristics needed to employ hydropower as a major source of electrical generation. Nevertheless, each region does show a certain degree of development potential; and with energy resources at a premium, the increasing utilization of this hydroelectric potential is likely.

Table 5-1 presents a summary of the number of sites, capacity and energy of the hydropower potential identified as most suitable. The table shows the

TABLE 5-1

NATIONAL TOTALS

	LESS THAN 5MW			5MW-30MW			30MW-100MW			MORE THAN 100MW			ALL SIZES		
	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH
EXISTING	761	1294	4920	449	5841	17402	79	4193	10593	39	8551	12536	1328	19880	45450
RUN OF RIVER	352	603	2356	194	2530	8827	31	1579	5205	13	2811	6447	590	7522	22835
CONDUIT	26	57	401	32	395	1299	9	527	1586	2	320	551	69	1299	3837
STORAGE	383	634	2163	223	2916	7277	39	2087	3802	24	5420	5537.	669	11058	18779
UNDEVELOPED	137	238	961	245	3744	15227	108	6245	20712	55	14628	37151	545	24855	74051
RUN OF RIVER	2	4	15	35	598	2546	19	1171	3914	6	1160	5542	62	2932	12017
CONDUIT	26	76	374	79	1076	5101	23	1098	4484	9	1563	3527	137	3812	13487
STORAGE	109	159	572	131	2070	7579	66	3977	12314	40	11906	28082	346	18111	48548
ALL SITES	898	1532	5881	694	9585	32629	187	10438	31305	94	23179	49687	1873	44735	119501
RUN OF RIVER	354	607	2370	229	3128	11372	50	2749	9119	19	3970	11989	652	10454	34851
CONDUIT	52	133	775	111	1471	6400	32	1625	6070	11	1883	4078	206	5112	17323
STORAGE	492	793	2735	354	4987	14856	105	6064	16116	64	17326	33619	1015	29169	67326

TABLE 5-1 (Continued)

NORTH ATLANTIC

	LESS THAN 5MW			5MW-30MW			30MW-100MW			MORE THAN 100MW			ALL SIZES		
	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH
EXISTING	373	541	2011	115	1403	3941	13	601	943	2	212	134	503	2756	7029
RUN OF RIVER	276	414	1555	77	939	2773	6	299	516	1	107	22	360	1759	4866
CONDUIT	2	3	-4	14	181	416	2	92	206	0	0	0	18	276	617
STORAGE	95	124	461	24	283	753	5	209	221	1	105	112	125	721	1546
UNDEVELOPED	66	70	311	27	407	1162	5	320	992	5	1699	6098	103	2497	8564
RUN OF RIVER	0	0	0	2	41	137	1	99	240	1	408	3575	4	548	3952
CONDUIT	0	0	0	3	61	205	0	0	0	0	0	0	3	61	205
STORAGE	66	70	311	22	305	821	4	221	752	4	1291	2523	96	1888	4407
ALL SITES	439	611	2323	142	1810	5103	18	921	1935	7	1912	6232	606	5253	15593
RUN OF RIVER	276	414	1555	79	980	2909	7	398	756	2	515	3597	364	2308	8818
CONDUIT	2	3	-4	17	242	621	2	92	206	0	0	0	21	337	822
STORAGE	161	195	772	46	587	1573	9	430	973	5	1396	2635	221	2608	5953

CENTRAL

	LESS THAN 5MW			5MW-30MW			30MW-100MW			MORE THAN 100MW			ALL SIZES		
	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH
EXISTING	114	229	938	107	1352	3752	20	1062	4468	7	1090	3470	248	3733	12628
RUN OF RIVER	40	105	495	47	545	2088	16	875	3878	4	628	2538	107	2153	8999
CONDUIT	1	3	91	2	32	213	0	0	0	0	0	0	3	35	304
STORAGE	73	121	352	58	775	1452	4	187	590	3	462	932	138	1545	3325
UNDEVELOPED	4	9	16	2	32	78	3	209	355	6	1547	2282	15	1798	2731
RUN OF RIVER	0	0	0	0	0	0	0	0	0	1	108	280	1	108	280
CONDUIT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STORAGE	4	9	16	2	32	78	3	209	355	5	1439	2002	14	1690	2451
ALL SITES	118	239	954	109	1384	3830	23	1271	4823	13	2637	5752	263	5531	15358
RUN OF RIVER	40	105	495	47	545	2088	16	875	3878	5	736	2818	108	2261	9279
CONDUIT	1	3	91	2	32	213	0	0	0	0	0	0	3	35	304
STORAGE	77	130	367	60	807	1530	7	396	945	8	1901	2934	152	3235	5776

TABLE 5-1 (Continued)

PACIFIC NORTHWEST

	LESS THAN 5MW			5MW-30MW			30MW-100MW			MORE THAN 100MW			ALL SIZES		
	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH
EXISTING	51	120	534	58	724	2484	22	1158	2795	12	3197	4973	143	5199	10786
RUN OF RIVER	4	9	38	12	151	482	5	212	353	4	1239	2422	25	1610	3294
CONDUIT	11	28	186	13	138	537	5	306	1187	1	190	412	30	661	2322
STORAGE	36	84	310	33	435	1466	12	640	1255	7	1768	2139	88	2927	5170
UNDEVELOPED	28	89	442	98	1509	7413	40	2229	9268	16	5154	16934	182	8981	34056
RUN OF RIVER	0	0	0	7	116	664	10	606	2425	2	338	1191	19	1059	4281
CONDUIT	19	63	325	50	700	3273	13	596	2305	2	273	1153	84	1632	7056
STORAGE	9	26	117	41	693	3475	17	1027	4538	12	4543	14589	79	6289	22719
ALL SITES	79	209	976	156	2233	9897	62	3387	12063	28	8351	21906	325	14179	44842
RUN OF RIVER	4	9	38	19	266	1146	15	817	2778	6	1577	3613	44	2669	7575
CONDUIT	30	90	512	63	838	3810	18	903	3492	3	463	1565	114	2294	9378
STORAGE	45	110	427	74	1129	4941	29	1667	5793	19	6311	16728	167	9216	27889

PACIFIC SOUTHWEST

	LESS THAN 5MW			5MW-30MW			30MW-100MW			MORE THAN 100MW			ALL SIZES		
	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH
EXISTING	67	109	467	16	230	820	7	326	631	6	1704	1760	96	2368	3678
RUN OF RIVER	2	5	28	1	16	21	1	39	133	1	260	362	5	321	545
CONDUIT	9	15	80	0	0	0	0	0	0	1	130	139	10	146	220
STORAGE	56	88	358	15	215	798	6	286	498	4	1313	1259	81	1902	2913
UNDEVELOPED	5	6	27	6	96	583	13	786	2364	8	2925	6040	32	3813	9015
RUN OF RIVER	0	0	0	0	0	0	1	91	205	0	0	0	1	91	205
CONDUIT	5	6	27	2	18	59	2	120	263	2	585	841	11	730	1191
STORAGE	0	0	0	4	77	524	10	575	1896	6	2340	5199	20	2993	7619
ALL SITES	72	115	494	22	326	1403	20	1112	2995	14	4629	7801	128	6181	12693
RUN OF RIVER	2	5	28	1	16	21	2	130	338	1	260	362	6	411	750
CONDUIT	14	22	108	2	18	59	2	120	263	3	715	980	21	876	1411
STORAGE	56	88	358	19	292	1322	16	861	2394	10	3653	6458	101	4894	10533

TABLE 5-1 (Continued)

ROCKY MOUNTAIN

	LESS THAN 5MW			5MW-30MW			30MW-100MW			MORE THAN 100MW			ALL SIZES		
	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH
EXISTING	54	78	294	27	330	791	6	382	389	3	583	499	90	1373	1973
RUN OF RIVER	3	6	23	6	100	155	1	66	48	0	0	0	10	172	226
CONDUIT	1	2	8	1	8	12	2	129	193	0	0	0	4	139	214
STORAGE	50	70	262	20	222	624	3	187	148	3	583	499	76	1062	1533
UNDEVELOPED	4	8	27	29	411	1884	8	314	1025	8	1658	2811	49	2391	5747
RUN OF RIVER	0	0	0	1	24	64	0	0	0	1	181	267	2	205	331
CONDUIT	2	7	22	24	297	1564	6	232	745	2	233	685	34	769	3016
STORAGE	2	1	5	4	90	256	2	82	280	5	1244	1859	13	1417	2400
ALL SITES	58	86	321	56	741	2675	14	696	1414	11	2241	3310	139	3764	7720
RUN OF RIVER	3	6	23	7	124	219	1	66	48	1	181	267	12	377	557
CONDUIT	3	9	30	25	305	1576	8	361	938	2	233	685	38	908	3230
STORAGE	52	72	267	24	312	880	5	269	428	8	1827	2358	89	2479	3933

PLAINS

	LESS THAN 5MW			5MW-30MW			30MW-100MW			MORE THAN 100MW			ALL SIZES		
	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH
EXISTING	32	69	201	49	712	2592	4	201	678	6	1169	957	91	2150	4428
RUN OF RIVER	4	11	46	22	359	1705	1	54	122	1	263	448	28	686	2321
CONDUIT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STORAGE	28	58	155	27	353	886	3	147	556	5	905	509	63	1464	2107
UNDEVELOPED	25	42	93	34	474	1485	11	709	1732	1	107	87	71	1332	3397
RUN OF RIVER	1	0	1	8	123	509	2	103	377	0	0	0	11	226	887
CONDUIT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STORAGE	24	42	91	26	351	976	9	606	1355	1	107	87	60	1106	2510
ALL SITES	57	111	294	83	1186	4076	15	910	2410	7	1276	1045	162	3483	7825
RUN OF RIVER	5	11	47	30	482	2214	3	157	499	1	263	448	39	913	3208
CONDUIT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STORAGE	52	100	247	53	704	1862	12	753	1911	6	1012	597	123	2570	4617

TABLE 5-1 (Continued)

SOUTH ATLANTIC

	LESS THAN 5MW			5MW-30MW			30MW-100MW			MORE THAN 100MW			ALL SIZES		
	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH	NUMBER	CAP-MW	ENG-GWH
EXISTING	70	148	474	77	1090	3022	7	465	689	3	597	743	157	2300	4928
RUN OF RIVER	23	54	171	29	421	1602	1	34	155	2	313	655	55	822	2583
CONDUIT	2	6	39	2	36	121	0	0	0	0	0	0	4	42	161
STORAGE	45	88	264	46	634	1298	6	431	534	1	284	88	98	1437	2184
UNDEVELOPED	5	14	46	49	815	2622	28	1678	4976	11	1538	2898	93	4044	10542
RUN OF RIVER	1	4	13	17	293	1172	5	272	667	1	125	229	24	694	2082
CONDUIT	0	0	0	0	0	0	2	149	1171	3	472	848	5	621	2019
STORAGE	4	10	33	32	522	1450	21	1256	3138	7	941	1821	64	2728	6441
ALL SITES	75	162	520	126	1905	5644	35	2142	5664	14	2135	3641	250	6344	15470
RUN OF RIVER	24	58	184	46	714	2774	6	306	822	3	438	884	79	1516	4665
CONDUIT	2	6	39	2	36	121	2	149	1171	3	472	848	9	663	2180
STORAGE	49	98	297	78	1156	2749	27	1687	3672	8	1225	1909	162	4165	8626

national title as well as a breakdown for each region. The site summary in Table 5-1 was drawn from the NHS data base. While not all of these sites will be developed the totals represent a good estimate of the likely development in each region by the year 2000. The environmental assessment uses these estimates to indicate the amount of hydropower additions that will be developed in each region.

The table categorizes the sites by status; whether at an existing dam or undeveloped site; the proposed operation of the site, run-of-river, storage, or conduit; and by size, less than 5 MW, 5-30 MW, 30-100 MW, and greater than 100 MW. These categories, as discussed in Chapter 2, are useful in discussing the distinction in environmental effectss.

The national summary shows that most sites are at existing dams (1328) rather than undeveloped sites (545). From an environmental standpoint, this is positive, because additions of hydropower at existing dams generally have less impact than at undeveloped sites. However, most of the capacity and energy (24,855 MW and 74,050 GW) are at undeveloped sites. Thus, if significant additions to the hydroproduction base are to be realized, undeveloped site impacts will have to be addressed.

One characteristic that influences where hydropower will be absorbed into a load curve is its general operational mode. Run-of-river facilities, with relatively natural continuous flows, are most often used to generate base-load power. Hydropower is extremely efficient in this type of operation when compared with thermal generation. Run-of-river power plants achieve efficiencies between 85 and 90 percent, whereas thermal plants rarely obtain better than 30 to 33 percent (Ruedisili and Firebaugh, 1980). Hydropower facilities operated as storage facilities are, in general, producers of peaking power. A significant impoundment of water can be controlled and then released quickly for meeting peak demands.

Conduit sites are generally irrigation or water supply links that have the potential for addition of hydropower. There is no storage associated with these links so the sites can be considered run-of-river. However, the operation of the water supply or irrigation systems often coincides with need for electricity by a water or irrigation district so the sites match peak demand. Again, the national summary shows that most sites and capacity and energy are associated with storage (1,015, 29,168 MW, 673,266 MWH) rather than run-of-river projects (652, 10,454 MW, 348,516 MWH). Impacts associated with storage projects are generally greater than run-of-river projects.

The final categorization shows the breakdown by size. Their breakdown reveals an important characteristic of the hydropower resource. By far, most sites are under 30 MW nationwide (1592). However, most capacity is at sites greater than 30 MW (33,616 MW). Over half of the capacity is at 945 sites greater than 100 MW. Specific environmental studies are needed to assess the impact of many, very small sites as well as a few very large sites. Analyses must consider the environmental impact versus the power obtained, yet there is no generally accepted means for making these tradeoffs.

2. Regional Energy Mix

For perspective, projections of expanded hydropower development must be evaluated in light of the current and future energy mix in each region to fully understand their ramifications.

At present, electric power plant systems in the United States are fueled by one of five major natural resources. Although many possible energy sources are now being explored, hydropower, coal, oil, natural gas, and nuclear power account for more than 98 percent of the present on-line capacity. A comparison of those resources on a nationwide basis shows that hydropower produced 11 percent of the available electricity in 1979. Concurrently, coal fueled 46 percent of the power generated; oil and natural gas contributed 17 percent and 14 percent, respectively. Nuclear power accounted for the remaining 12 percent (SRI International, et. al., 1980).

These figures accurately describe power production from a national perspective, but they do not provide a clear picture of the regional power characteristics. The interrelationship between the available fuel sources in each region varies according to regional features, resources, and policies. To outline the regional distribution of hydropower and other fuels, and to provide a basis for environmental comparison, the energy mix of each of the seven study regions has been compiled. A summary appears in Tables 5-2 and 5-3.

Consistent with historical trends, the demand for electrical energy in the United States is growing. An average annual demand increase of 4.2 percent is predicted from now through 1989. Projections from major utility companies indicate continued growth through the 1990s, but at a slightly lower rate (approximately three percent annually). In terms of total electrical consumption, estimates for the year 2000 show a 50 percent increase over current use (DOE, 1979).

At present, the nationwide energy mix predicted by DOE for the year 2000 shows the combined oil- and gas-fired generation to be reduced by almost 60 percent from 1980 levels. Oil-fired generation represents eight percent of the year 2000 mix and natural gas use is estimated at five percent. Offsetting the reductions are increases in coal and nuclear generation. Coal-fired generation is projected to rise to 51 percent of the total, and nuclear generation is shown as 25 percent of the mix, more than double its 1980 proportion. The total annual energy produced by hydroelectric facilities will have increased, but the proportion of hydropower will remain at about 12 percent (DOE, 1979).

On a regional basis, the projected electrical demands and fuel mix vary considerably. The study regions are growing at different rates and have disparate resources and power situations (Tables 5-4 and 5-5).

Other sources of energy must be expanded if the projected levels of hydropower development cannot be achieved. The probable replacements will depend on the existing and proposed fuel mix found in each region. The exact composition of the mix cannot be determined given the inherent uncertainty

Table 5-2

1980 ELECTRIC GENERATION BY FUEL TYPE (%)

Study Region	Oil	Natural Gas	Coal	Nuclear	Hydropower	Alternative Sources
Total U.S.	17	14	46	12	11	--
Pacific Northwest	--	--	24	4	72	--
Pacific Southwest	34	25	12	5	20	4
Rocky Mountain	--	8	60	2	30	--
Plains						
Lower	--	76	23	--	1	--
Upper	15	1	57	15	12	--
Central	4	--	1	--	85	10
North Atlantic						
Lower	60	--	11	12	18	--
Upper	63	--	2	20	14	--
South Atlantic	27	--	50	14	9	--

Sources: SRI, 1980 and SPA estimates.

Table 5-3
1980 INSTALLED ELECTRIC GENERATING CAPACITY
BY FUEL TYPE (MW)

Study Region	Oil	Natural Gas	Coal	Nuclear	Hydropower	Alternative Sources
Total U.S.	151,400	74,900	228,900	53,600	73,900	1,000
Pacific Northwest	--	--	4,200	2,000	26,400	--
Pacific Southwest	30,000	13,000	5,000	1,500	12,800	1,000
Rocky Mountain	--	1,300	11,100	200	5,200	--
Plains						
Lower	--	59,000	9,600	--	2,500	--
Upper	5,900	1,600	25,000	3,800	3,200	--
Central	23,900	--	114,800	16,700	5,600	--
North Atlantic						
Lower	32,000	--	4,200	6,100	5,500	--
Upper	13,000	--	500	4,500	2,700	--
South Atlantic	30,600	--	54,500	16,500	12,400	--

Source: DOE, 1980.

Table 5-4
PROJECTED ELECTRIC GENERATION BY FUEL TYPE IN THE YEAR 2000 (%)

Study Region	Oil	Natural Gas	Coal	Nuclear	Hydropower	Alternative Sources
Total U.S.	8	5	51	25	11	--
Pacific Northwest	1	--	24	10	65	--
Pacific Southwest	24	20	23	9	20	4
Rocky Mountain	9	5	60	1	25	--
Plains						
Lower	1	60	25	12	2	--
Upper	10	5	62	12	10	1
Central	8	5	60	20	2	5
North Atlantic						
Lower	20	--	28	35	17	--
Upper	22	--	18	51	9	--
South Atlantic	8	2	60	20	9	1

Sources: DOE, 1979 and SPA estimates.

Table 5-5
PROJECTED INSTALLED ELECTRIC GENERATING CAPACITY
BY FUEL TYPE IN THE YEAR 2000 (MW)

Study Region	Oil	Natural Gas	Coal	Nuclear	Hydropower	Alternative Sources
Total U.S.	157,900	75,500	383,000	205,000	95,300	4,500
Pacific Northwest	1,500	--	6,200	13,400	29,300	--
Pacific Southwest	34,000	1,600	11,800	15,200	15,200	1,000
Rocky Mountain	1,200	1,000	32,500	340	6,200	--
Plains						
Lower	6,200	58,500	40,700	14,700	2,600	--
Upper	7,400	5,600	44,000	7,300	4,500	300
Central	26,400	1,800	156,500	52,500	8,500	1,700
North Atlantic						
Lower	33,200	--	7,800	22,400	8,400	--
Upper	13,300	--	1,000	11,400	2,800	--
South Atlantic	29,700	5,500	79,100	65,000	17,800	1,500

Source: DOE, 1980.

involved in projecting electricity demand and supply in multi-state regions. Assuming that reliance on oil and natural gas must be reduced wherever possible and the balance required between peaking and base load power must be maintained, Table 5-6 presents the types of generating capacity that could substitute for hydropower capacity. Due to economic uncertainties, these estimates can only be considered to be approximate.

c. Regional Assessment of Hydropower Development and Environmental Impacts

The magnitude of development and the type of hydropower facilities projected vary substantially by region. Moreover, the physical changes caused by this development depend primarily on the ecological characteristics of the region and, specifically, on the characteristics of the sites. For example, while passage of anadromous fish around dams is a major concern in the Pacific Northwest and North Atlantic regions, only 60 percent of the dams in those regions might have anadromous fish present in the vicinity of the proposed project (INTASA, 1980). Because of the locational aspects for most impacts, quantitative assessments by region are not possible. Rather, the major issues and concerns discussed in Chapters 3 and 4 create the framework for identifying and discussing qualitatively the potential environmental impacts of the projected development.

In the following section, regional energy development and its effects are summarized. Given the substantial uncertainty in the location, amount, and timing of the development, more detailed evaluations are not possible.

1. Pacific Northwest

The natural topographic characteristics and abundant water resources of the Northwest have encouraged extensive development of hydroelectric facilities. Almost three-quarters (72 percent) of all electricity in the region is supplied by conventional hydropower. The remaining power needs are met primarily by coal-fired plants (24 percent), with nuclear plants

Table 5-6

PROBABLE REPLACEMENT SOURCES OF ENERGY FOR HYDROPOWER, BY REGION

Study Region	Replacement
Pacific Northwest	coal, nuclear
Pacific Southwest	coal, nuclear
Rocky Mountain	coal, oil
Plains	nuclear, oil
Central	nuclear, oil
North Atlantic	coal, nuclear
South Atlantic	coal, nuclear

generating the remainder (4 percent). The use of oil and natural gas for power production is minimal (Corps, 1980).

The Pacific Northwest's demand for electrical energy is growing at a rate that is slightly higher than the national yearly average (4.5 percent compared with 4.2 percent). Estimates indicate that keeping up with this rising need will require changes in the present energy pattern (DOE, 1979). As noted, the Pacific Northwest's existing power base is hydroelectric generation. However, as new hydropower sites become limited, the region will be forced to add some new thermal generating facilities in addition to substantial conservation efforts. This will be a major transition for the region's power industry and will alter the current energy mix (DOE, 1979; Pacific Northwest River Basins Commission, 1980).

Projections for the year 2000 anticipate hydropower to remain the basis of the regional power scheme, but constituting 65 percent of the total instead of the present 72 percent. Coal-fired generation is forecast to remain fairly constant at 24 percent. Nuclear facilities are estimated to be the growing thermal energy source in this region, as compensation for the hydropower limitations. They represent 10 percent of the year 2000 fuel mix. The remaining one percent are primarily oil-fired facilities used for peaking power (DOE, 1979).

Not surprisingly, the Pacific Northwest, with the largest current use of hydropower, dominates the potential development forecasts. Projections indicate a total of 325 feasible sites in this four state area. This represents 17 percent of the potential facilities within the contiguous United States. The outstanding fact, however, is that the projected sites in this region account for over 30 percent of the expected incremental energy from hydropower nationwide.

The majority of the 325 hydropower sites (56 percent) are presently undeveloped. This large, untapped reserve is unique to this region and accounts for most of the estimated power. The remaining 143 sites (44 percent) occur at existing dams and diversion structures, where new or additional power facilities are feasible. Many of the existing sites are already generating power to some extent and therefore show lesser incremental capacities.

The projections identify 167 (51 percent) of the sites as storage operations, 44 (14 percent) as run-of-river operations and 114 (35 percent) as conduit facilities, which involve any of several configurations. The storage facilities predominate in the Northwest, both in number and energy output. They total to 65 percent of expected new regional hydro capacity and over 60 percent of expected new average annual energy generation.

Overall, the regional study estimate defines 14,179 MW of available incremental capacity in the Northwest. This additional capacity could potentially generate 44,841GWh annually.

The Pacific Northwest is unique among the regions because only here are large, storage facilities at new sites projected to be the predominant type of hydropower facility constructed. As discussed in Chapter 3, these facilities are the least environmentally acceptable among all hydropower types and create the most profound effects on the environment. Moreover, this region accounts for over 30 percent of the total potential capacity nationwide. Nearly one million acres of reservoir surface area would be created by the proposed development.*

The effects of this magnitude of development in the Pacific Northwest are expected to be substantial. Anadromous fish, which are important commercial commodities along all of the coastal waters, extend far into the interior of the region. Creation of large impoundments in place of free-flowing streams could degrade the aquatic environment and cause a decline in fish population. Although some mitigation is possible using fish passage facilities, fish hatcheries, or operational changes in release patterns, some damage to the population size and diversity cannot be avoided (refer to Chapter 7). In the case of endangered or threatened species, the damage may be irreversible. Some Indian tribes in this region rely on fishing for livelihood and consider it to be an important part of their cultural heritage. They have sought and won substantial legal authority not only for guaranteed fishing rights, but also for maintenance of a high quality aquatic environment.

The projected development will also have a major effect on water quality. In this region, fluctuations in temperature and flow below the dam are of most concern; stratification of reservoirs occurs infrequently. During hot summer months, pulses of cold water are released from dams to generate peaking power causing physical changes in the flow regime and morphology of the stream (Graf, 1980). Secondary effects include degradation of aquatic and riparian habitat as well as recreation. New techniques for selective water withdrawal are currently used to correct these temperature impacts.

Loss of riparian habitat and white-water recreation, two issues of major concern in the region, would be adversely effected by the creation of

---

* Calculated from average reservoir surface areas for each hydropower type presented in Appendix C.

additional storage. Although white-water recreation can sometimes be accommodated by changing operating procedures, riparian habitat is seldom replaced or enhanced by such development or mitigation measures (Oliver, 1975). As a result, some reductions in terrestrial wildlife will accompany the projected development.

This region would increase dependence on coal-fired and nuclear generation if projected expansions of hydroelectric capacity are not achieved. The impacts from generation of nuclear power were discussed in Chapter 3. Generally, they do not vary by region except with respect to the distance over which uranium fuel or nuclear waste must be transported. The overall impacts of nuclear power are small when compared to the other energy types (refer to Figure 3.6). However, some important concerns go undetected in such broad comparisons: (1) The occupational and public health risk associated with operation of a nuclear plant, particularly near a populated area; (2) the environmental damage and human risk associated with uranium mining and fuel processing; (3) the safety issues associated with transport of uranium fuel and nuclear waste, and (4) the disposal and containment of high-level nuclear waste. A nuclear plant can supply large, firm capacity (typically 1,000 MW) for baseload power versus hydropower's typically smaller (30-100 MW) often nonfirm capacity that can, however, be used for peaking power. These tradeoffs must be considered before a series of rationale energy choices can be made for the Pacific Northwest region.

Coal-fired power plants are most typically used to generate baseload power. Montana is included in the Pacific Northwest region where coal resources are abundant. As mentioned in Chapter 3, the primary impacts associated with this energy source result from air emissions and disposal of sludge and ash. Depending on the chemical quality of the coal, power plants emit various quantities of SO_x, NO^x, and hydrocarbons, which can have deleterious effects on human health and contribute to smog and the development of photochemical oxidants. Electrostatic precipitators that capture more than 90 percent of the pollutants are generally required before operating permits are issued. In this region, temperature inversions that trap pollutants and keep them from dispersing downwind are rare and, therefore, emissions from coal-fired power plants may not pose a major problem. However, this region does have a number of wilderness and other areas designated as Class I. Any energy facility must demonstrate that it will not deteriorate the air in those regions (i.e., meet PSD standards-- "Prevention of Significant Deterioriation"--established by EPA). This has become a major issue in Montana where planned expansions of the Colstrip power plant and development by the Crow tribe has been thwarted by designation of Class I air over the Cheyenne reservation to the east.

2. Pacific Southwest

The electrical power structure of the Pacific Southwest has a diverse fuel base. All conventional power resources are employed to some degree, and several alternative energy sources are now producing electricity, although their output represents a small percentage of the total.

Conventional oil- and gas-fired steam plants generate 34 percent and 25 percent of the regional total, respectively. Proportionately, oil and gas fuel an even higher percentage (67 percent) in California. Southern California relies heavily on oil for its power production (Corps, 1980). Hydropower facilities produce 20 percent of the regional power, and are principally located in northern and central California and western Nevada. Coal-fired plants generate 12 percent of the regional power, and are dispersed throughout the three state area. Three on-line nuclear power plants, all in California, provide 5 percent of the region's output (DOE, 1978).

Unique to the region is commercial power production from a geothermal source. The Geysers (technically fumaroles) area in northern California currently has 13 operational units with a total capacity that accounts for two percent of the regional total. The remaining two percent of the regional power is supplied by a combination of solar and wind power projects, which are all relatively new and, in general, are experimental or demonstration efforts (PG & E, 1978).

The projected increase in power demands in the Pacific Southwest parallel those of the Pacific Northwest, at 4.5 percent per year from now into the 1990s. The percentage of power generation by fuel type is expected to change in keeping with these demands. It is anticipated that the region will follow national trends and substantially reduce its use of oil and natural gas for electrical generation (DOE, 1979).

The power scheme for the year 2000 in the region shows oil-fired generation as contributing 24 percent of the total and natural gas generation as adding 20 percent. Those are both extensive reductions from the 1980 operating levels. Offsetting these decreases are increases in coal, nuclear, and hydropower generation. Coal is forecast as contributing 23 percent of the future mix, almost double its present use. Nuclear facilities are ranked as producing nine percent of the future power output, and hydropower plants total 20 percent. That is an 80 percent increase in nuclear power and about a five percent increase in existing nuclear power capacity and about a five percent increase in hydropower. The remaining four percent of the regional electricity is estimated as a combination of geothermal, wind, and solar production (DOE, 1979).

The Pacific Southwest region has an estimated 128 hydropower sites capable of being developed or expanded. This is approximately seven percent of the United States total. Seemingly small in comparison with the Northwest, this region nevertheless represents the third largest incremental capacity in the nation - more than 6,100 MW.

Most of the 128 sites (83 percent) are at existing dams. One hundred and one of these are storage facilities, six are run-of-river operations and twenty-one are conduits. These existing locations total to 2,368 MW of additional capacity. Additions to existing plants would generate 3677 GWh or 29 percent of total expected new hydro energy.

Of the 32 completely new sites, 20 are storage facilities, 11 are conduits and one is a run-of-river operation. The undeveloped storage facilities account for the bulk of the estimated power, as all but four of them are more than 30 MW in capacity. Overall, these sites make up 3,813 MW of capacity and would add 9,014 GHh KWh or 71 percent of new hydro power output.

The region, as a whole, could acquire an average of 12,693 GWh of additional energy per year as a result of fully developing all 128 sites. This would amount to eleven percent of the electrical energy estimated to be available from hydro expansion nationwide.

Most of the projected development in this region is expected to take place in California. The majority of the 6,181 MW of additional capacity is at undeveloped storage sites that would be constructed to provide 30 MW or more of capacity. Nearly 150,000 acres of reservoir surface area would be created by new storage projects.

Anadromous and migratory fish are found along the coastal and some inland streams of California. Existing reservoir development in the state has significantly reduced their populations. The California Fish and Game Department and the U.S. Fish and Wildlife Service may view the projected development of existing dams as an opportunity to restore spawning runs to tributaries above projects, significantly adding to development costs and perhaps making many projects economically infeasible.

The addition of hydropower facilities to an existing dam can adversely affect the flow regime if operated to produce peak-load power. Reduction in dissolved oxygen and fluctuations in temperature below the dam can also be expected from releasing deep reservoir water during periods of stratification (Tudor Engineers, 1978). However, these effects could be minor if the reservoir operation is not changed significantly with the addition of power.

Because water from reservoirs in California is allocated by a complex legal system, development of hydropower at existing dams may come in conflict with other water users. Hydropower generation does not consume water, however, it may require releases at times when other water users cannot take advantage of the increased flow in the stream. Significant compromises may have to accompany such development unless dams are retrofit to operate as run-of-river facilities and to generate power whenever water is released for other purposes. Several license applications to FERC have already been made for just this type of operation (e.g., City of Ukiah, 1980).

The creation of new reservoirs in this region raises two additional issues of concern: protection of wild and scenic rivers and endangered species. The California legislature has wrestled for years with the recurring issue of wild and scenic rivers. Some interest groups promote dam construction on the few remaining wild stretches on Northern California rivers, primarily for water supply. Others fight for maintaining the status of state-designated wild and scenic rivers. Similarly, protection of state and federally-designated endangered species may come in conflict with reservoir development. Creation of new impoundments that raise either of these concerns could require lengthy review and project delays until resolution is achieved.

This region would increase dependence on coal-fired and nuclear generation if projected expansions of hydroelectric capacity are not achieved. The environmental impacts linked to these two energy types have been described in Chapter 3 and in the previous section about the Pacific Northwest region. The pacific Southwest has several important differences. Most of the demand for electricity is centered in California, where strict siting laws and strong public opposition to locating energy facilities in populated areas have severely limited the choices of utilities. California is prone to severe earthquakes and has few acceptable sites for nuclear power plants. The urban areas of the state are subject to severe air quality problems and thus cannot be the site for a coal-fired plant unless other industries reduce their emissions and allow the coal facility to purchase pollutant offsets from them. If such facilities were targeted for siting in the uninhabited areas of the Pacific Southwest region, water supply for the facilities becomes a major obstacle. Furthermore, regional coal resources are found primarily in

Arizona where water supply, Indian rights, and export of energy are major issues. Clearly, some tradeoffs are necessary to identify reasonable energy choices for this region.

3. Rocky Mountain

The Rocky Mountain region shares some energy characteristics with the Pacific Northwest. Its natural topographic relief yields abundant hydropower opportunities, which is reflected in the regional power scheme. While not the primary power producer, hydropower is highly significant, accounting for 25 percent of the regions electricity. The bulk of the regional power supply (60 percent) is derived from coal-fired steam generation. Oil and natural gas supply about 14 percent with about 1 percent attributable to one on-line nuclear plant in Colorado (DOE, 1978a). Like the Pacific Northwest area, this portion of the country currently has little dependence on oil for the production of electricity.

The growth rate of the Rocky Mountain region is similar to that of the other western states. The total electrical capacity of the region will have to double within the next 20 years to keep pace with the demand. The projected power scheme, designed to meet these needs, shows a significant increase in coal-fired steam generation and hydropower. Whereas the capacity produced by these fuels will increase, their relationship to the total generation remains almost constant. Coal as a fuel source will still be responsible for approximately 60 percent of the regional power output. Hydropower will represent slightly less than its current percentage, totaling about 25 percent. The remaining portion (15 percent) is made up of a number of fuel and generation types. Nuclear power will represent only one percent of the region's electrical generation (only one plant, in Colorado, is anticipated to be on line in this region). Gas and oil together constitute almost all the rest (14 percent) of the regional total. The only other expected source is geothermal; however, it will be a very small fraction of the total. Natural gas and oil will be used for both steam and turbine generation. Their most important role will be to supply adequate peaking capacity (DOE, 1979).

The Rocky Mountain region has more total sites than the Pacific Southwest, 139 versus 128 , but only 60 percent as much incremental capacity (3,764 versus 6,181 MW). Many of the sites (42 percent) involve new or additional projects of only 5 MW or less. Sixty-five percent of the regional total occurs at existing sites. Much of the potential in this region has already been tapped. This does not imply that the smaller projects are insignificant however. Developing all the hydro sites in this area will allow the region to obtain an average of 7,719 GWh of additional electrical energy annually.

There are a total of 49 undeveloped sites (35 percent). Thirty-four of these are conduits, thirteen are storage plants and two are run-of-river installations. They represent 64 percent of the incremental capacity in this region (2,391 MW).

The remaining 90 sites are located at an existing dam or diversion structure and include projects covering all of the operational types. Ten of the existing sites (13 percent) are listed as run-of-river operations. The majority (84 percent) are storage operations. Of the projects located at storage facilities, almost two-thirds (65 percent) would be additions smaller than 5 MW. The last 4 projects (3 percent) at existing dams are classified as conduit operations. The total incremental capacity that is available at all 90 locations is 1,373 MW or 36 percent of the regional total.

As in the Pacific Southwest, hydropower development at existing dams in this region is also expected to come in conflict with existing water users. Each state has its own policy for allocating water that classifies best uses and assures a supply for those with the most senior rights. Therefore, the retrofitting of existing dams will be sized to generate power only when releases are being made for other purposes (e.g., flood control or irrigation). In this case, environmental impacts are expected to be minor.

The creation of new reservoirs has attendant problems that are particularly acute in this region. Many streams are designated or under study as part of the federal (or state) wild and scenic river system. Some attractive hydropower (or multipurpose reservoir) sites may impinge on these streams. This region has above-average demand for white-water recreation, stream fishing, and wilderness recreation that could be seriously affected in some locations by such development. The remaining stretches of free-flowing streams and substantial acreages of wilderness are carefully guarded by state legislatures and some interest groups.

Additionally, although new reservoir development creates assured storage in this water poor region, the loss of water by evaporation offsets this benefit. In fact, the water allocation system accounts for evaporation as a debit to the total available supply for each state (Colorado River Compact). This tradeoff must be thoroughly evaluated before a new project can be considered.

The Rocky Mountain region would increase dependence on coal and oil-fired generation if projected expansions of hydroelectric capacity are not achieved. Coal has been discussed previously and the impacts expected here are similar to those described for the Pacific Southwest. In this case, however, the main focus of energy demand is the metropolitan Denver area and the major coal resources are located somewhat closer to the demand--northwestern Colorado, northwestern New Mexico and Wyoming. Temperature inversions are frequent along the Front Range of the Rocky Mountains. As a result, energy facilities would most likely be constructed on the plains to the east or at the mine. This gives rise to socioeconomic problems related to housing and providing services for construction and operation personnel in rural areas.

Oil-fired generation has a dual purpose--it can supply both baseload and peaking power. As discussed in Chapter 4, the emissions from such facilities are lower than those from coal facilities. Nevertheless, hydrocarbons, NO_x and SO_x are still emitted from these facilities and do contribute to reduced air quality. Local oil supplies are available in Wyoming and Colorado, but escalating prices and decreasing overall supply should point the way toward reducing reliance on this energy source. Once again, this region must evaluate the tradeoffs among these various energy sources to make rational decisions about the source of future capacity.

4. Plains

The Plains region encompasses such a large and diverse number of states that no one set of energy data applies to the entire region. However, a somewhat natural break occurs between what can be considered the upper plains (Minnesota, the Dakotas, Nebraska, and Iowa) and the lower plains (Kansas, Missouri, Oklahoma and Texas). Note also that Iowa and Missouri only marginally fit into the energy picture for the Plains states; their power-production characteristics are more similar to those of the Central region (DOE, 1979).

The lower plains states primarily employ only two fuel sources for electrical production - natural gas and coal. Interestingly, Texas and Oklahoma still produce the most oil in the contiguous United States, yet oil-fired power plants are almost non-existent there. Natural gas, also plentiful in the region, is used for 76 percent of the electrical output of the lower plains. Coal-fired plants are accountable for 23 percent of the available power, and the last one percent is produced from hydroelectric sites. Presently, the region contains no on-line nuclear plants (DOE, 1978).

Compared with the lower Plains, the upper Plains states use a larger combination of fuel to sustain their electric systems. Oil does play a role in the upper plains, accounting for 15 percent of capacity. Coal, however, ranks first, producing 57 percent of the electrical power. Nuclear power there matches oil use (15 percent of the energy mix). Hydropower is more prevalent in the upper plains than in the lower regions, and makes up 12 percent of the power output. Natural gas is the least used (contrast with the southern plains states) and fuels only 1 percent of the power supply (DOE, 1979).

The lower Plains states encompass some of the fastest-growing areas in the nation. With that growth, annual electrical demand is expected to increase at a full percentage point higher than the national average--approximately 5.2 percent per year. The transition from the present fuel mix to the expected mix for the year 2000 will create important changes in this area's power base by the introduction of more fuel types than are currently employed (DOE, 1979).

Natural gas use is expected eventually to be reduced from more than 75 percent to 60 percent. Coal-fired steam generation will probably be expanded to more than 25 percent of the lower Plains' power structure. In addition, nuclear facilities will probably be incorporated, and are expected to represent almost 12 percent of the total power supply. The remaining three percent will probably consist of hydropower and oil-fired steam generation plants (DOE, 1979).

The upper Plains region is growing at a slightly lower rate than the four lower Plains states (4.5 percent as opposed to 5.2 percent). Fuel mix changes will not seem as dramatic in the upper Plains area because of its present distribution of power resources. The major change will probably be a decrease in oil-fired generation. Coal will probably contribute 62 percent of the energy mix and oil, only 10 percent. Nuclear capacity will probably stay relatively unchanged, thereby becoming a smaller percentage of the future mix, estimated as 12 percent of the projected electricity supply. As with nuclear power, hydropower is anticipated to drop somewhat in the projections, to 10 percent. The last six percent is expected to be a composite of natural gas generation and small cogeneration facilities. Alternative fuels sources (solar, wind or geothermal) are not expected to account for any part of the regional power systems (DOE, 1979).

The Plains region exhibits the fewest number of future hydropower sites relative to its geographical expanse. Projections show 162 sites throughout the nine-state area capable of generating additional energy. The combined capacity of all 162 hydropower sites is 3,483 MW. This incremental capacity is estimated to produce an annual average energy output of 7,825 GWh.

The number of undeveloped and existing sites are almost equal. There are 71 undeveloped sites and 91 existing locations. Most of the undeveloped sites (85 percent) would function as storage operations. The remaining 15 percent are run-of-river facilities. As a whole, the undeveloped category accounts for 38 percent of the regional incremental energy estimate. There are no undeveloped conduit operations in the Plains region. Twenty-five of the undeveloped sites (35 percent) are designated with capacities under 5 MW. The remainder have capacities greater than 5 MW, however only 10 sites (14 percent) are larger than 30 MW.

The 91 sites where new or expanded facilities could be developed are mostly (69 percent) at existing dams classified as storage facilities. In general, these represent projects where additional generating units could be incorporated, as indicated by the large number (60 percent) of small and medium-range capacities. The other 30 percent of the existing sites are all classified as run-of-river operations. Four of the run-of-river projects are less than 5 MW and 24 are greater than 5 MW.

This region is the largest geographically; yet is projected to have the potential for the smallest additional capacity. Approximately 3,500 MW of capacity is projected, primarily at new sites operated as storage facilities and with 30 MW or more of capacity. The projected development could create more than 160,000 of reservoir surface area.

Because much of this region has flat terrain, reservoirs typically have large surface areas with respect to their volume. Thus, valuable agricultural land or riparian habitat could be lost.

New reservoirs are also effective in trapping the high sediment loads common in the region. Although this may be a benefit to those using water downstream, erosion usually increases markedly below the dam changing the flow regime and often adversely affects adjacent land uses. Additionally, the high sediment loads shorten the usable life of the reservoir and can increase maintenance costs of the hydropower facilities.

Adverse effects on the aquatic ecology are also expected from the potential development. Some degradation of the important warmwater fishery in the southern Plains region is expected. Turbine mortality and entrapment along the Missouri River could adversely affect commercial fishing there. Finally, endangered species, such as the paddlefish or the Colorado squawfish, could be adversely affected by creation of new reservoirs upstream.

Because the opportunities for hydropower development in this region are limited, given its large geographic extent, other sources of energy will have to be developed regardless of what happens in the hydropower area. In this region, nuclear and oil-fired power plants are likely candidates for development. Their associated impacts will be similar to those described in Chapter 3 and previously in this section. As for other regions, the selection of rational energy choices requires an evaluation of tradeoffs.

5. Central

The Central region relies on coal for almost its entire electrical supply. There, coal fuels 85 percent of the generating plants, for the highest use percentage of any fuel source in all seven regions. Coal is plentiful in many states of the central region and that, unquestionably, is the primary basis for such a high use level. In addition, other power-producing natural resources, such as oil and gas, are not abundant. Consequently, nuclear power is used for 10 percent of the remaining needs. The last 5 percent is split between power from hydroelectric sites (4 percent) and oil-fired plants (1 percent) (DOE, 1979).

The Central region is currently one of the slower-growing areas in the country. Its demand for power, however, is still increasing, and, by 2000, it may require as much as 70 percent more electricity than in 1980. The region's cornerstone is coal-fired generation, and estimates are that it will continue to be. Its relative percentage is expected to drop, however, as other sources, particularly nuclear, increase. Coal is projected as 60 percent of the fuel mix and nuclear as 20 percent. Hydropower represents only two percent of the energy mix in projections for the year 2000. Oil and gas generation are expected to increase to a total of 13 percent. That is a large increase, prompted undoubtably by the region's large peaking demand. With coal and nuclear facilities being primarily base-loaded operations, and with limited hydropower and alternative sources, oil and gas must be relied on for extra power in peak-demand periods. The last five percent of the region's future generation scheme is attributed to a combination of alternative sources, including solar, geothermal, and cogeneration (DOE, 1979).

The Central region contains 12 percent of the nation's hydropower development potential. Two hundred and sixty-three sites have been identified as feasible additions to the regional power system. A unique feature of this region is the almost complete lack of undeveloped sites. Only fifteen of the 263 sites (6 percent) are listed as undeveloped. While many of the regional water resources have been developed, the power resources associated with them have not. With a large number of existing dams showing the potential for power additions, this region could add 3,733 MW of electrical capacity with possibly minimal environmental impacts.

A further breakdown of the data shows that 138 of the 256 locations (56 percent) are existing storage sites. The existing run-of-river installations total to 107 sites (43 percent) and there are three (one percent) existing locations that qualify as conduits. The energy output available at these sites is approximately 12,628 GWh per year. Many of the existing projects (46 percent) are rated at less than 5 MW, however, their collective generation can be very important to the regional electrical system. Almost as many existing sites (43 percent) have power values denoted as 5-30 MW, and their combined capacity can achieve 42 percent of the electrical energy that is available at existing dams. Remarkably, there are 27 existing sites capable of generating power in excess of 30 MW. These 27 sites could augment regional capacity by 2,150 MW and annual energy output by 7,938 GWh.

The undeveloped sites, while few in number, represent 32 percent of the estimated incremental capacity and 18 percent of the possible annual energy generation. Of the 15 sites, 15 are storage operations and one is a run-of-river operation. There are no conduit sites where development is expected to occur. The capacity range for the undeveloped projects shows four as under 5 MW, two between 5 MW and 30 MW, and nine as greater than 30 MW. These nine larger sites contribute significantly to the regional hydropower potential.

The overall regional projection indicates a possible 5,530 MW of combined new and additional capacity. This capacity would result in an average of 15,358 GWh of additional electrical energy per year. Most sites are existing storage reservoirs with capacities of 30 MW or less. Only a small amount of development is expected at new sites as indicated by the small incremental reservoir acreage expected to be created--56,000 acres.

Development of hydropower at existing storage reservoirs in this region should have minor environmental problems. Because most dams in this region are used for flood control, hydropower releases for small capacity generation should not interfere. However, release of water through turbines rather than spilling water over the top of the dam may have some water quality effect. During periods of stratification, the water released through the turbines is colder and lower in dissolved oxygen than the natural streamflow. Thus, coldwater species may replace the natural warmwater fishery in the region. In addition, poor water quality from industrial and domestic discharges in many streams in this region can lead to higher than normal concentrations of pollutants in reservoir bottom waters. The stratified conditions cause heavy metals, pesticides, and organic material to enter solution and contaminate the release waters.

The U.S. Fish and Wildlife Service is making efforts to introduce Atlantic salmon to the Great Lakes. These salmon must use tributaries to spawn. Developers of new reservoirs may have to install costly fish passage facilities if the site is thought to interfere with fish movement.

This region would increase dependence on nuclear and oil-fired power plants if projected expansions in hydroelectric capacity are not achieved. As mentioned previously, their associated impacts are quite different from those related to hydropower. Demand for peak-load power is high in this region, particularly for heating or cooling during weekday working hours. Oil-fired generation will most likely meet additional demands for this type of power. Because oil is becoming an expensive and scarce resource, its use could cause economic hardship for the regional population. Pollution problems from oil-burning facilities can be minor if the location is properly selected. Similarly, nuclear power plants have relatively minor emissions to the environment at the plant site; but a whole range of other issues concerning risk of accidents and disposal of nuclear waste also come into play. This region, as all others, has certain tradeoffs that must be evaluated before rational energy decisions can be made.

6. North Atlantic

The North Atlantic covers a much smaller geographical area than some regions, but has two fairly different power grids. The lower segment of the region, including New York, New Jersey, and Connecticut, is a heavily industrialized and populated area, dependent on oil-fired generation for approximately 60 percent of its electrical power. Coal-fired plants account for 11 percent of the power supply there. Eleven on-line nuclear facilities generate 12 percent of the electricity for this sub-region. Hydropower represents a strong proportion of the energy mix, with a capacity that currently totals 18 percent of the overall power grid. The use of natural gas is insignificant in this section of the United States (DOE, 1979).

The upper New England sub-region employs the same fuels for power generation as the lower North Atlantic, but in slightly modified proportions. The outstanding difference is that coal-fired generation makes up only 2 percent of the available power. That is the smallest percent use of coal by the electrical industry in the United States. In compensation, however, the New England area uses more oil (63 percent) for electricity production than any other region in the nation. The area lacks many of the fossil fuel resources that abound in other regions, but is fortunate in that topographical features do provide some hydropower potential. Hydropower currently represents 14 percent of the energy mix, and further developments appear likely. Also special to the sub-region is the percentage of power obtained from nuclear plants. Whereas the actual number of nuclear plants is less than many other areas, the proportion of electricity they generate (20 percent) is the highest in the nation (DOE, 1979).

As in the Central region, anticipated growth in the North Atlantic region falls behind the national average. However, power demands are growing, and, by 2000, should be more than 50 percent greater than in 1980. As noted, the region has two distinct subregions. The New York and New Jersey area's projected fuel mix is one of substantial transformation. With a present dependence on oil of 60 percent, this area is expected to rely on oil for only 20 percent of its electrical needs in the year 2000. To offset this, coal use is expected to increase to 28 percent (2.6 times its 1980 level) and nuclear power is estimated to contribute 35 percent of the total (3 times its 1980 level). In relation, hydropower remains almost constant at 17 percent. Conservation must also play a major role in tempering the demand.

Likewise, projections for the upper New England area involve major shifts in generating sources. Oil and nuclear resources are shown as being almost reversed in the fuel mix forecasts. Nuclear resources are estimated as fueling 51 percent of the electrical supply in 2000 (up from 20 percent in 1980). Oil is reduced in importance from 60 percent of the load to 22 percent. Coal-fired plants are designated as 18 percent of the grid, and hydropower is reduced to nine percent. Again, these changes show this region to be in the greatest state of energy transition in the nation. Decreasing the reliance on oil will require major alterations to the entire regional power system (DOE, 1979).

The North Atlantic study region has the largest number of potential hydropower sites in the nation. Almost one-third of the 1,873 sites (606) under study are in this eight-state area. While there are numerous sites, they are characterized by small capacities and, therefore, the regional energy production from hydropower lags far behind the Pacific Northwest. The projected electrical energy from hydropower in the North Atlantic area is only 34 percent of the Pacific Northwest total.

Of the 606 sites, 503 are at existing dams and 103 are undeveloped. The large number of sites with an existing dam or impoundment (83 percent of the total) gives this category credit for the region's largest available capacity and energy. However, 373 (74 percent) of the existing sites are designated as projects with less than 5 MW capacities. Only 15 sites (three percent) are identified as locations capable of generating over 30 MW. The remaining 115 sites (23 percent) have capacities between 5 MW and 30 MW. All 503 existing sites can potentially augment regional capacity by 2,756 MW and produce an average of 7,029 GWh per year.

Of the exiting dam sites, 360 (72 percent) are run-of-river, 125 (25 percent) are storage and 18 (four percent) are conduits. Much of the potential associated with these sites is expected to be realized by retrofitting and upgrading older sites.

The undeveloped sites again are primarily sites with small capacities on an individual basis, but their total addition is significant. Four of the undeveloped locations (four percent) would be operated as run-of-river. However, the majority of the completely new facilities (93 percent) would be storage plants. The last 3 percent would be classified as conduits.

The development of these undeveloped sites with water resources suitable for hydropower works is estimated to result in 66 facilities (64 percent of the total) with capacities less than 5 MW. Twenty-six percent (27 sites) of the power plants would be rated between 5 MW and 30 MW. The other 10 sites (9 percent) are expected to have capacities exceeding 30 MW. These sites are crucial to the region's hydropower network if significant amounts of additional electrical energy are to be achieved.

The regional totals indicate that the North Atlantic can incorporate about 5,253 MW of additional capacity and 15,593 GWh of average energy production per year by developing its available hydropower resources. This is the second highest regional energy production in the United States and represents 13 percent of the nationwide total.

The North Atlantic region is unique in the type and number of hydropower projects that have potential for development. One-third of all potential sites are located there; also the predominant hydropower type is small run-of-river facilities at existing dams. Approximately 150,000 acres of new reservoir surface area may also be created.

Development of existing dams may come in conflict with the desire to preserve historical sites. However, some developments such as an historical park in Lawrence, Massachusetts, have used this to their advantage and received government funding to restore and improve dam sites while adding a hydropower component.

The U.S. Fish and Wildlife Service is restoring Atlantic salmon and American shad in coastal New England. Although development at existing dams would not further degrade aquatic habitat for these fish, the agency may view this as an opportunity to restore the fish to tributaries above the dam. As a result, costly fish passage facilities may be required as part of the licensing process.

This region would increase dependence on coal-fired and nuclear power if projected expansion of hydroelectric capacity is not achieved. The overwhelming majority of hydropower sites provide small capacity and nonfirm power; but the system to back up these sites is necessarily large and reliable--like coal-fired power plant. Coal is unique by its rarity as an electrical fuel source in the North Atlantic region. Any new coal-fired power plant will encounter some of the same siting difficulties mentioned for other regions. In addition, many urban areas in this region are suffering from poor ambient air quality that would be further degraded by a coal facility.

Nuclear power already provides a significant percentage of electricity in the region. Recently, public opposition to such facilities has heightened.

In summary, the particular hydropower resource in the North Atlantic cannot be effectively compared to the types of energy sources that would replace it. Generally, tradeoffs are necessary--sometimes among several regions--to select a series of energy choices that make sense.

7. South Atlantic

The South Atlantic region includes many states and sub-regions. Because of this, a diverse group of fuel sources forms the regional power grid. Coal-fired plants predominate, producing 50 percent of the total output. Oil is the fuel source for 27 percent of the regional electricity, and nuclear resources fuel another 14 percent. Hydropower installations generate the remaining balance of nine percent. While these figures are representative of the region as a whole; sub-regional energy characteristics are quite distinct in this study area (Corps 1980).

Florida, for example, has a much heavier dependence on oil than is reflected in the regional average. Hydropower facilities are almost non-existent in Florida, and coal is used to a much lesser degree there than in other states of the South Atlantic region. Most of the hydropower sites are located in the Carolinas and the Tennessee Valley. On-line nuclear installations are the most prevalent in Alabama, South Carolina, and Florida. However, nuclear facilities are operating, or nearing operation in every state in the region (DOE, 1978).

The South Atlantic region electric need is expected to grow at a rate of 4.3 percent per year into the next decade. Its fuel sources and power structure are diverse. Coal-fired generation is expected to continue to dominate the regional power grid, increasing to nearly 60 percent in the year 2000. An increase in nuclear power is predicted with the additional facilities, bringing it to 20 percent of the power supply. Hydropower will probably fuel about nine percent of the electricity generated. By 2000, the percentage of oil generation employed will be greatly reduced from 1980 levels, estimated as only eight percent of the energy mix. The last three percent represents a combination of natural gas generation (two percent) and pumped storage projects (one percent) (DOE, 1979).

The South Atlantic regional projections are very similar to those in the Central region. The individual site characteristics vary, but the expected electrical output, 15470 GWh per year, is within one percent. The total sites in the South Atlantic projections, 250, also parallel the Central regional data. The current status of the sites is distributed differently, however. More than one-third (36 percent) of the sites are undeveloped. The remainder are located at sites with an existing dam.

The undeveloped sites contribute significantly to the projections in this region. Sixty-four percent of the incremental capacity and almost 70 percent of the future energy generation from hydropower in the South Atlantic is dependent upon these undeveloped sites. Of these 93 undeveloped sites, 24 are designated as run-of-river operations; 64 are storage facilities and five are conduits. Contrary to many other regions, the untapped potential in this area does not consist of a large group of projects with capacities less than 5 MW. Only five undeveloped sites are listed in the under 5 MW category. Instead, the sites are almost split in half between the other ranges of 5-30 MW and over 30 MW. The mid-range totals to 49 sites (53 percent) and the upper range consists of 39 projects (42 percent). The summation of all of these sites shows a possible 4,043 MW of additional capacity and 10,542 GWh of additional electrical energy.

The existing 157 sites include 55 run-of-river locations, 98 storage operations and four conduits. The possible benefits from constructing or expanding power facilities at these locations include 2,301 MW of new capacity and 4,928 GWh of increased energy production. The majority (49 percent) of the power expansions at existing sites will result in projects between 5 MW and 30 MW in size. Many of the rest (45 percent) are capable of providing less than 5 MW of capacity. The remaining six percent, a total of 10 sites, are estimated as producers of 30 MW or more.

The sum of all the estimated hydropower development in this region shows 6,344 MW of expanded capacity. Overall, the South Atlantic states contain 14 percent of the nation's hydropower potential. Sites primarily at existing storage reservoirs 30 MW or less of capacity. More than 300,000 acres of reservoir surface could be created.

This region has already experienced severe problems from release of poor quality water from reservoirs during periods of stratification. If the existing dam has no hydropower at present, addition of turbines that release water from the hypolimnion could significantly degrade downstream water quality and the warmwater fishery.

The creation of lakes in this region with few natural lakes is a benefit. However, navigation is important and new reservoir construction could come in conflict with this use of the waterways.

American shad occur in some coastal tributaries. Some recent FERC license applications have required addition of fish passage facilities before approval was granted. If shad are present at many of the proposed sites, additional costs may be incurred by the developers to mitigate this problem.

This region will increase dependence on coal-fired and nuclear generation, if projected expansion of hydroelectric capacity is not achieved. Because this region encompasses the Appalachian states, coal resources are abundant. Thus, cost is low and distance to markets is short. The potential environmental problems associated with nuclear and coal-fired facilities have been described previously. Additionally, this region may encounter greater difficulty in obtaining acceptable disposal sites under RCRA because of the percentage of the region that might be considered "environmentally sensitive" by EPA. These area now include floodplains and wetlands, while areas of karst or limestone terrain (such as central Florida, much of Georgia and Alabama) are under consideration for such designation.

Hydropower cannot be compared, but only contrasted, with other energy sources. Each has specific tradeoffs that may be somewhat different for each region. The challenge is to evaluate them fairly and to select rational energy choices.

CHAPTER 6

HYDROPOWER PLANNING AND ENVIRONMENTAL LEGISLATION

A. History of Change

The discussion that follows presents a detailed review of federal legislation and policy concerning hydropower. It begins with a consideration of the federal role in the development of water resources at the beginning of this century, and continues through an examination of environmental legislation designed to soften the impacts of hydroelectric development.

1. Historical Review

The legislation that has influenced hydropower development has taken several directions throughout the first three quarters of this century. Although not all of these choices evoke controversy today, they are examined to provide a background for understanding the legislative framework for hydropower. In addition, as the renewed interest in hydropower increases, controversy may recur over any of these points.

During the first part of the century, the federal government's role in water resource activity expanded and conflicts over the private use of public waterways became a heated issue. Private power development stalled amid Congressional opposition to some projects and Presidential vetoes defeating other (Corps, 175). To remedy the situation, the Congress passed the Federal Water Power Act (now the Federal Power Act) (PL 66-280) in 1920. It was landmark legislation. Among other things, the Act accomplished the following:

- Established a Federal Power Commission (FPC) (now Federal Energy Regulatory Commission) with authority to publish regulations and issue licenses for the development of non-federal hydroelectric power

- Made all licenses for nonfederal use subject to the provisions of a comprehensive plan for the watershed

- Prohibited private development when it should be developed by the United States

- Required that licensed projects charge reasonable rates

- Declared that the business of transmitting and selling electric energy to the public was a matter of public interest (Corps, 1975)

With the Act, the government decided that the best way to protect the public interest was to establish a regulatory system to control hydropower developed by the private sector. From 1920 to 1940, total hydroelectric capacity tripled from that of the previous era.

Extensive federal participation in hydropower began during the Great Depression of the 1930s. The federal government became actively interested in rural economic development, which became an implicit goal of federal water resource projects. During this period, flood control became "a proper federal activity" (Flood Control Act of 1936, PL 74-736) and the sale of power from the hydropower component of the project supported the unstated goal of economic development. The sale of power provided a significant benefit to cover the costs of the development and operation of a project, and Congressional approval was based on the benefit-cost analysis (Corps, 1975). Many of the projects that Congress authorized were designed to bring electricity to those areas of rural America where private power companies had not provided adequate service. In the Flood Control Act of 1938 (PL 750685), Congress authorized the Corps to install facilities for future power use, where feasible, on its reservoir projects.

Under the Bonneville Project Act of 1937, the Congress created the Bonneville Power Administration (BPA) within the Department of Interior (now within the DOE) to market the power produced at the Corps-constructed project on the Columbia River. The Act encouraged the "wildest possible use" of all electric energy that could be generated and included provisions that municipally owned power systems and rural cooperatives should receive preferential rates for the purchase of power.

By the end of the 1930's, federal agencies were involved in all phases of hydropower development--generation, operation, and marketing. During the 1940s, vigorous debate centered on the Government's decision to generate power at dams built primarily for other purposes (National Water Commission, 1973). The government's competitive role was increased by the Flood Control Act of 1944 (PS 78-534), which contained provisions for the sale of power at Corps' projects. Under the Act, the Secretary of the Interior was charged with the responsibility to dispose of power "at the lowest possible rates to consumers consistent with sound business principles." Clauses for sales at lower rates to preferred customers--rural co-ops and public bodies--were retained from the precedents established in previous legislation.

The legislation of the 1930s and 1940s was sufficient to support the growth of federal hydropower during the 1950s. Total capacity tripled between 1940 and 1960; however, hydropower's share of the total U.S. electric capacity declined between 1950 and 1970, while the nation's growing energy demand was filled primarily by a significant expansion in steam-powered development (See Figure 6.1). The federal share of hydroelectric output showed tremendous growth between 1950 and 1977, as shown in Figure 6.2. The 1950s was the first time that the investor-owned share of hydropower capacity began to drop below the federal share as many federal projects became operational.

Major legislation during the 1960s and 1970s has been enacted to protect and enhance environmental quality. Environmental legislation, such as the Wild and Scenic Rivers Act and the National Environmental Policy Act. (NEPA), are discussed later in this chapter. As a result of revisions to the Principles and Standards for water resources development, protection of the environment became one of the major elements of Corps' projects along with promoting economic development as objectives to be met in federally-financed

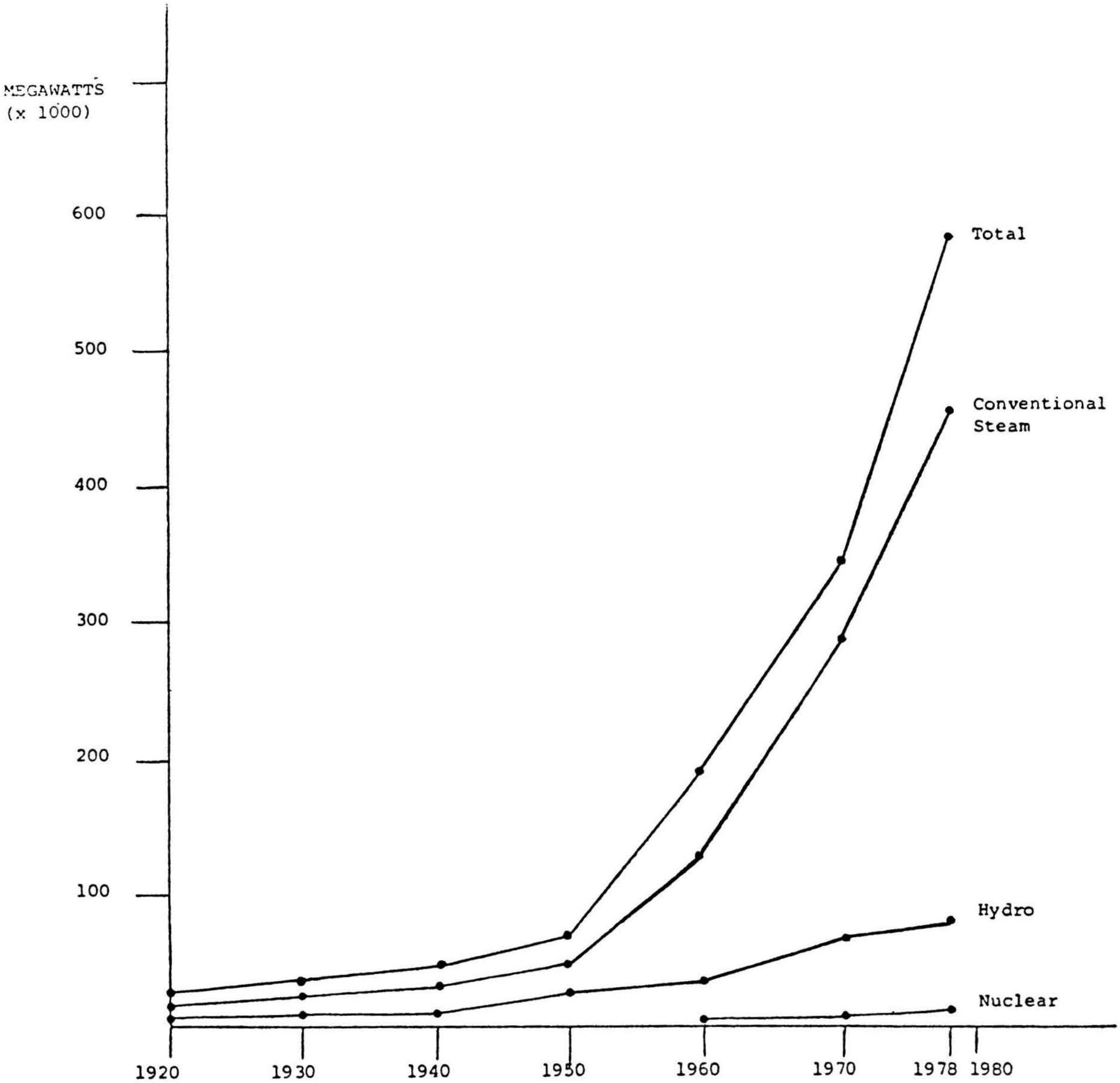


Figure 6.1a INSTALLED GENERATING CAPACITY OF THE ELECTRIC UTILITY INDUSTRY, 1920-1978

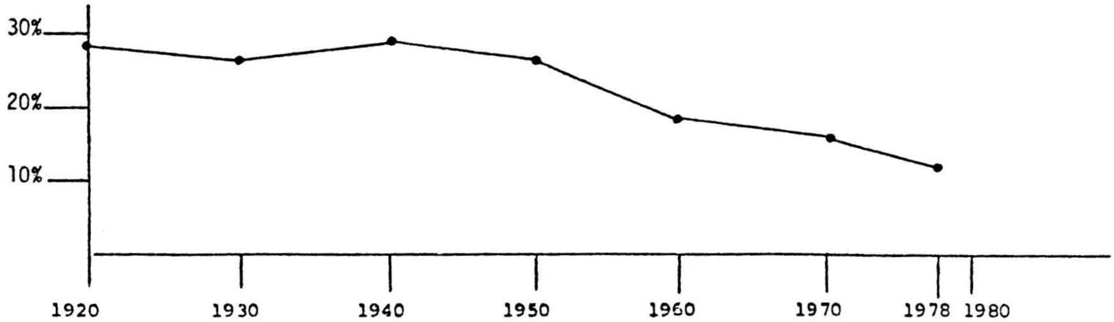


Figure 6.1b HYDROPOWER'S SHARE OF TOTAL ELECTRIC UTILITY INDUSTRY GENERATING CAPACITY

Sources: Edison Electric Institute, 1974 and 1979;
GAO, 1980a and 1980

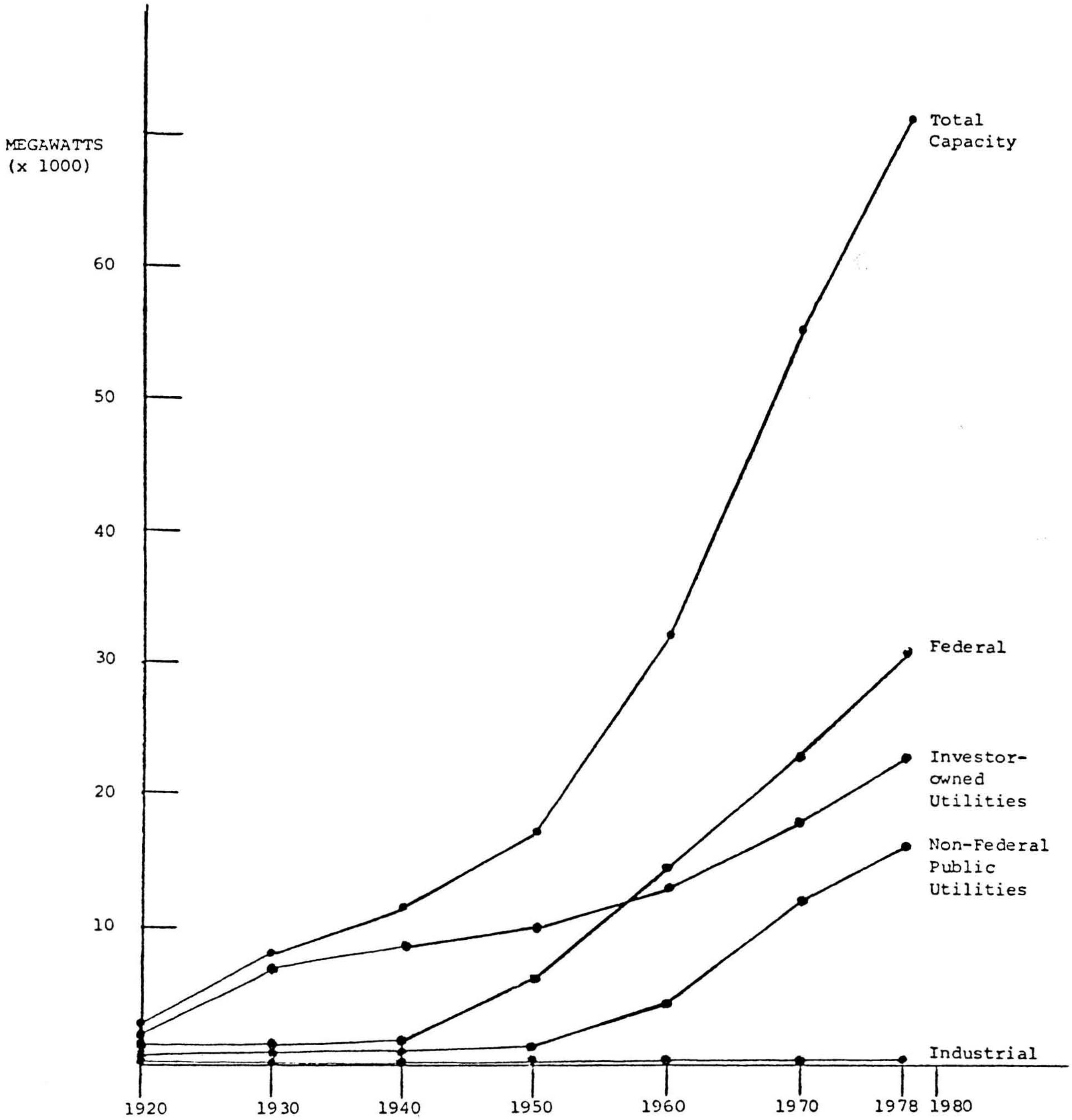


Figure 6.2 CONVENTIONAL HYDROELECTRIC CAPACITY BY CLASS OF OWNERSHIP, 1920-1977

Source: Edison Electric Institute, 1974 and 1979 water resources projects (River and Harbor and Flood Control Act of 1970, PL 91-611).

In the present era of environmental consciousness, some observers question whether the federal government's legislative mandate to promote the widest possible use of power at the lowest possible price is still appropriate (Corps, 1975). Since the 1930s, provisions encouraging "the widest possible diversified use of electric energy" (Bonneville Project Act, 1937) at "the lowest possible rates consistent with sound business principles" (The Flood Control Act of 1944) have formed the basis for the extensive development of federal hydropower. The viewpoint of the non-federal sector has been that power should be marketed at a price that will provide a fair rate of return for the federal investment and also reflect taxes that are foregone (Price, 1971).

2. Recent Developments

The OPEC oil embargo of 1973-1974 represents a turning point in America's energy use and consideration of energy. Its initial impact was long lines at the gas pumps and colder homes and offices. An additional discomfort hit the pocketbook; prices began increasing steadily for a heretofore relatively inexpensive necessity--energy. The impacts have been felt in many aspects of American life. Interest in hydropower, especially in examining capacity at existing sites, has grown since 1974. Legislation passed since 1974 reflects a new interest and commitment by the Congress and the President to use the country's hydropower to develop an energy source independent of foreign control. Central to the recent hydropower legislation and policy is the notion that, even with the promotion of hydropower, the protection of the environment is not to be sacrificed.

Since 1974 private interest in developing hydropower has increased dramatically, as evidenced by the recent increase in applications for FERC licenses (See Figure 6.3). Congress has directed federal agencies to undertake several initiatives to support the private development of

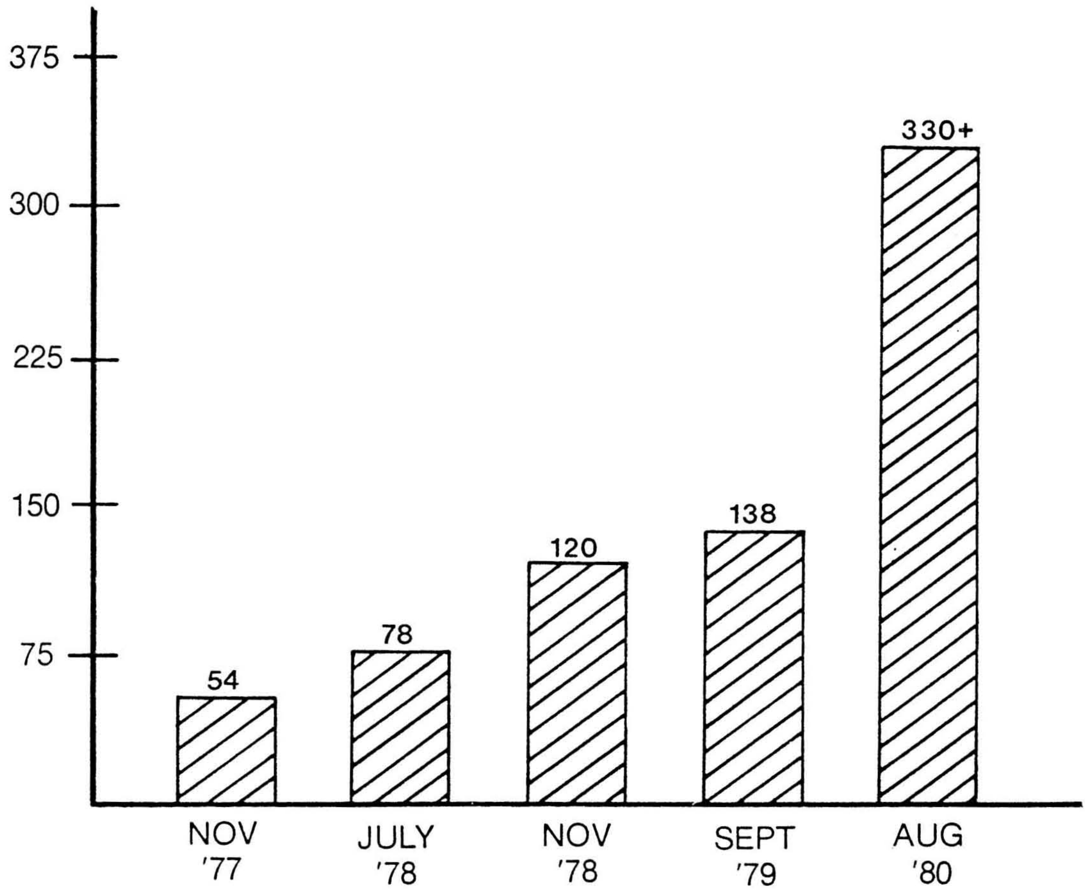


Figure 6.3 FERC APPLICATIONS FOR LICENSES AND PRELIMINARY PERMITS
Source: GAO, 1980a; Energy Users Report, 1980a.

small-scale hydropower. With its establishment in 1977, the DOE made hydropower one of its eight programs on which to focus for commercialization (GAO, 1980a). With the passage of The Public Utilities Regulatory Policy Act (PURPA), DOE was authorized to promote small-scale hydropower. Under its Small Hydro Program, DOE was mandated to foster the development of small hydropower projects at existing sites, through a feasibility study program and a demonstration program. The Congress has continually appropriated more money for the programs than DOE or the Office of Management and Budget (OMB) has requested. In addition, OMB has decided not to request the $300 million construction loan appropriation authorized under the PURPA because OMB believes the development would go ahead without the loan program (GAO, 1980a).

Changes have also lightened the regulatory burden. Under PURPA, the FERC was directed to streamline its licensing policies for existing hydropower facilities with capacities of less than 15 MW, and to exempt facilities with capacities of 30 MW or less from certain requirements. PURPA also required that utilities purchase power at reasonable rates from hydropower facilities with capacities of 80 MW or less.

The federal government provided federal tax and investment credits for developers of small-scale hydropower resources under the Crude Oil Revenue Code of 1954. In addition, hydropower projects with an installed capacity of up to 124 MW are now eligible for support through tax-exempt revenue bonds (Energy Users Report, 1980c).

The streamlining effort of FERC received further support from the Congress in the Energy Security Act of 1980 (PL 96-294). Section 408 grants FERC the authority to exempt hydropower projects with capacities of up to 5 MW on a case-by-case basis or by class or category from its licensing requirements. The exemption, however, was in no way to jeopardize the environment, and full compliance was intended with statutes such as the Fish and Wildlife Coordination Act, the Endangered Species Act, and the National Environmental Policy Act (NEPA) before any exemption was issued (U.S. Senate, 1980).

A theme that pervades the recent hydropower legislation and federal policy is an emphasis on increasing the contribution of non-federal, small-scale hydropower. The promotion of small-scale hydropower contrasts markedly with the pattern of the past 50 years, when non-federal hydropower was strictly regulated, rather than encouraged. Without a shift in the current direction of federal hydropower policy, the Corps and the Water and Power Resources Service (WPRS) will be unable to provide significant new hydropower capacity in the near future (WPRS, 1980). These development agencies heretofore have played no significant role in the development of small-scale hydropower. They are now examining their potential future role, because small-scale hydropower projects are generally considered less environmentally objectional than large projects, and more likely to be built.

B. Federal Versus Non-Federal Development

1. Federal Hydropower

Hydropower development is divided into two areas--federally-sponsored projects and projects sponsored by private or non-federal interests. The responsibilities of the various agencies and the agencies' role in hydropower are related to whether they directly affect federal or non-federal activities. Historically, congress has treated each sector in a different manner. For almost 50 years, Congress has been supporting the expansion of public power through the development of multi-purpose water resource projects. Only in the past few years has non-federal hydropower received new emphasis in federal legislation.

Many federal agencies today are involved in the development of hydropower. For some, dealing with hydropower has long been a significant part of their responsibilities; for others, the present interest in hydropower has expanded into a heretofore insignificant area. Table 6-1 shows the category of activities that each agency undertakes. As the table shows, the Tennessee Valley Authority (TVA) is the only agency with significant activities in at least six categories. The table also illustrates that ten agencies provide

Table 6-1

ROLES OF FEDERAL AGENCIES
IN HYDROPOWER DEVELOPMENT

TYPE	FEDERAL HYDROPOWER					NONFEDERAL HYDROPOWER				
ACTIVITY	CORPS	WPRS	TVA	BPA	OTHER POWER MARKETING ADMINS.	FERC	DOE	REA	FmHA	OTHER RURAL ENERGY INITIATIVE AGENCIES
Research	o	o	o	o			o			
Planning	o	o	o	o						
Financial Support							o	o	o	o
Licensing/ Permitting	o		o			o				
Construction	o	o	o							
Operation	o	o	o							
Power Marketing			o	o	o					

financial and/or technical assistance in developing nonfederal hydropower potential or performing studies to determine the federal hydropower potential.

Three federal agencies--the Corps, WPRS, and TVA--construct and operate hydropower facilities. The power marketing administrations, including the BPA, sell federal power at wholesale rates, giving preference to publicly and cooperatively owned distribution systems.

The Corps is the nation's largest single producer of hydroelectricity. It has constructed and now operates 67 projects with a capacity of almost 18,300 MW (Corps, 1979). In 1978, Corps' facilities produced 87.2 billion kilowatt-hours that represented about 31 percent of the total U.S. hydroelectric production and 4 percent of all electric energy produced in the nation that year. Almost all of the agency's power production has become operational since 1950. Hydropower typically is one element of a multi-purpose Corps' project whose primary purpose is either flood control or navigation.

The Bureau, the second largest producer, has planned, built, and now operates 50 facilities with a total hydropower capacity of 9,700 MW. The projects are located in the 17 Western states, and include such famous developments as Hoover Dam on the colorado River and Grand Coulee Dam on the Columbia.

Like the Corps, the Bureau does not sell the electricity it generates to consumers. Rather, it sells power to the Federal Power Administrations, which then market it. Also like the Corps, the Bureau has become a major producer of hydroelectric power, largely as an indirect result of its irrigation and reclamation activities.

The TVA is a public corporation chartered by the Congress. It is the third-largest producer of federal hydropower, with an installed capacity of

3,256 MW. The legislative goals of the Authority are to regulate the streamflow of the Tennessee River, primarily for the purposes of promoting navigation and controlling floods, but also "to provide and operate facilities for the generation of electric energy" whenever such an opportunity arises (PL 76-259). The TVA's principal activity is the production of electric power at 37 TVA-owned dams and 12 Alcoa-owned dams located in the Tennessee River Valley System. The TVA is also a marketing agency, and distributes power at wholesale rates to more than 160 municipal and cooperative electric utilities that serve 2.5 million people. Within its jurisdiction, the TVA also is authorized to issue a permit to any developer who intends to construct or retrofit a dam (Brown and Buxton, 1979).

The BPA is a marketing agency of the DOE. BPA began selling power from the Bonneville Dam in 1937, and now markets power from virtually every federal dam in the Pacific Northwest. It has constructed its own transmission lines to market power to almost 150 customers that include 116 public utilities and 17 electro-process industries. BPA's transmission system, the largest high-voltage network in the country, consists of about 12,500 miles of high voltage lines (Durocher, 199). The cost of power in the Northwest is about one-half the national average; the regional consumption is double the national average. BPA thus appears successful in responding to its original statutory mandate: to promote the widest possible diversified use of power at the lowest possible rates.

2. The Planning Process

For either a federal or a nonfederal hydropower project, the transition from an interest in promoting a hydropower project to planning and actual development can be a lengthy process. This section will examine the overall planning process for developing a hydropower project and will focus especially on environmental compliance both for federal and nonfederal projects.

a. The Federal Planning Process

When the Corps undertakes a study authorized by congress, it seeks to identify and assess the problems and needs of the water and related resources in the area under study, determine potential alternative solutions, and select the most feasible plan or solution (Corps, 1974). The development of a federal project is shown by the steps in Figure 6.4. In this case, the Corps receives authorization from Congress to study a problem and determine a solution. Determining the solution and deciding on the project is the Corps' responsibility (Steps 4-6). At this stage, the Corps district engineer evaluates the economic, environmental,and social effects of the project, and estimates the tangible benefits, costs, and cost sharing. The district engineer then prepares a report that passes an extensive review process (Steps 6-8) both within the Corps and among other federal agencies, states, and the public. For a hydropower project, the review would involve consulting with the power marketing agency that would sell power from the project, as well as with FERC. The Corps draft and revised draft environmental impact statements (EIS) are published during this time. A final report, including the final EIS, is prepared for the Secretary of the Army (Step 9). After review by the Water Resources Council (WRC) and OMB (Step 10), the project becomes part of the package sent to Congress for authorization each year. In Congress, it may or may not be authorized (Step 11-12). If authorized by Congress, the Corps begins a process of advanced project planning, by performing additional planning and detailed design work (Step 13-16). Such work can continue for years, and may require further Congressional authorization to produce construction plans and specifications. The final steps include the award of a construction contract and construction of the project (Steps 17-18).

Environmental compliance is a major component of the study preparation and review process (Steps 5-9). Consideration of the environment for a Corps project, and other federal project, is prescribed by NEPA. NEPA-based planning has two major national objectives: national economic development (NED) and environmental quality (EQ). The EQ objective provides the framework for developing a plan that considers compliance with environmental regulation

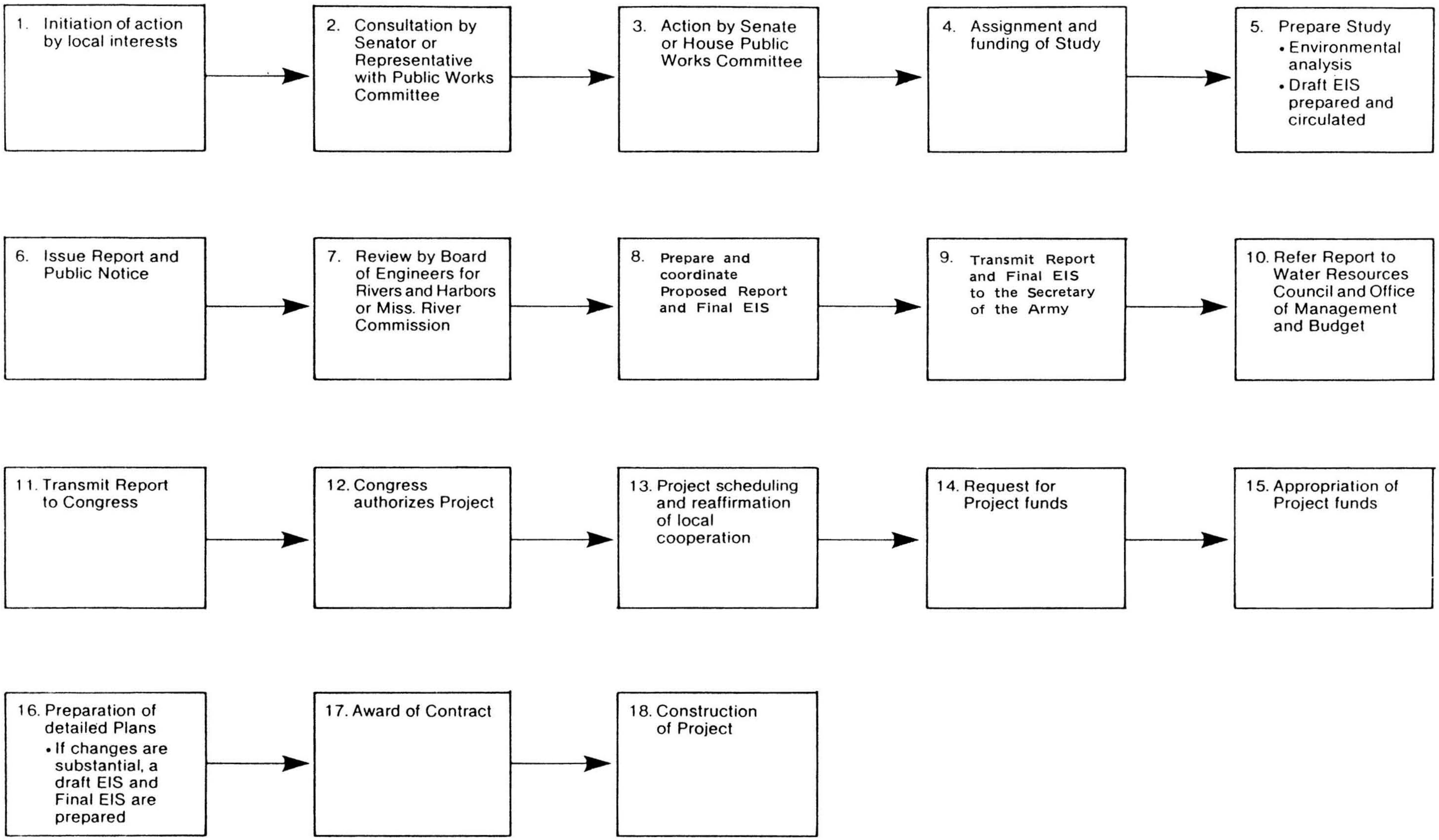


Figure 6.4 CORPS PROCESS

Est. time: 15 years

Source: Corps, 1974 rev.

and policy. The general components if the EQ objectives are the following (Water Resource Planning Associates, 1980):

- Preservation of areas of natural beauty and human enjoyment. This could include avoiding damaging impacts to wilderness, wild and scenic rivers, and esturine areas.

- Preservation of valuable or outstanding archeological, historical, geological, biological resources (especially fish and wildlife habitat), and ecological systems.

- Enhancement of water, land, and air quality by controlling pollution or preventing erosion. This component seeks to balance economic use of the land with conservation of the resource.

- Avoiding irreversible commitments of resources to future uses by exercising caution in meeting any development objectives.

- Other components relevant to the level of the planning effort.

Before authorizing a project, the Congress must determine that the project will serve a need, be well-designed, economically feasible, and enhance environmental quality (Corps, 1979). The Corps; process to develop a multi-purpose water resource project involves many steps, and may take more than 15 years to complete (GAO, 1980a).

B. Nonfederal Project Planning

The development of a nonfederal project subject for FERC's licensing requirements differs greatly from the development of a federal project. Figure 6.5 outlines the FERC licensing process. The FERC determines whether or not the applicant has filed an adequate license application in Step 5. Prior to that stage, the applicant may have filed a preliminary permit to hold a site (Step 2) and commenced negotiations with other federal agencies to

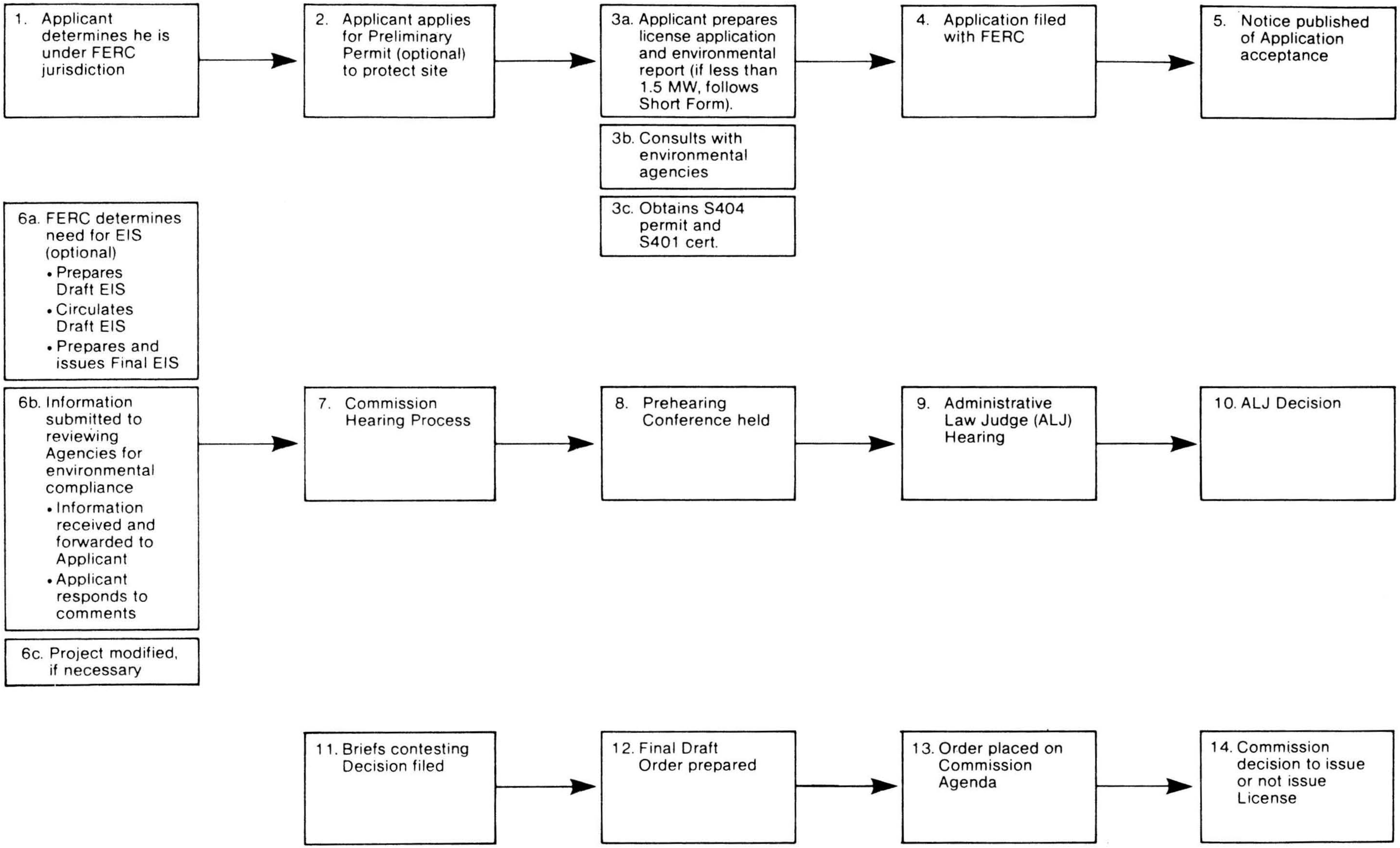


Figure 6.5 FERC PROCESS

Time: 4 – 6 years

Source: FERC, 1979; Brown & Buxton, 1979.

develop its environmental report (Step 3). After FERC accepts an application, it must decide if an EIS needs to be developed on the project. Preparation of the draft EIS and the final EIS must be completed before a formal hearing process begins (Steps 6-7). After a series of hearings and internal FERC decisions, the commissioners then draft an order on whether or not to issue a license (Steps 8-14). The licensing process can take several years to complete even after the applicant has completed significant work before submitting the license application.

The FERC licensing process provides two separate steps for environmental compliance. The first activity (Step 3) leads to the preparation of an environmental report (Exhibit E) as part of the license application (FERC, 1979), and precedes an applicant's filing of a formal license application with FERC. The scope of the exhibit depends on the size of the proposed project. For a project of less than 1.5 MW capacity, the applicant would submit only a brief environmental report. However, the applicant would still have to comply with all the existing federal and state environmental statutes and regulations. The major âdministrative difference between this facility and a larger one is that FERC would not prepare an EIS on the project because the agency does not consider issuing a license to the facility to be a major federal action that would have significant affect on the environment.

For larger facilities,* FERC also requires the applicant to complete a more comprehensive environmental report that contains seven main elements, including the following (FERC, 1979):

- o General description of the locale
- o Water use and quality
- o Report of fish, wildlife and botanical resources
- o Report on historical and archaeological resources

---

*FERC has issued a proposed rule (December 1980) that would allow some facilities with capacities of 5 MW or less to qualify for an exemption and thereby require no environmental report, although some states may require one independently.

- o Report on recreational resources
- o Report on land management and aesthetics
- o List of literature.

In the environmental report, the applicant discusses all aspects of the consumptive use of project waters and the impact of the project on water quality. Included, for example, are descriptions of any flow releases, measures to protect water quality, and the incremental impact of the project. The applicant would consult with the EPA, the Corps, and state water agencies. The applicant must also obtain a Section 401 water certification from the designated state agency.

The measures taken by the applicant to comply with various fish and wildlife resources also must be documented. For example, the applicant would consult with the U.S. Fish & Wildlife Service about the possible presence of endangered species. If there may be an impact on anadromous fish, the National marine Fisheries Service will have to be consulted. One major section of the report would include the need for fish passage facilities and a detailed description of how they would be maintained or constructed.

In examining historical and archaeological resources, the license applicant would examine the National Register of Historic Sites to determine if the site could be affected by operation of the facility. If the project site is not on the register, the applicant would take the necessary steps to determine if the site should be eligible. If requested by a reviewing agency, the applicant may have to conduct an archaeological survey in the area of the facility.

Recreational opportunities are often provided at hydropower facilities. The applicant must consult with the U.S. Heritage Conservation and Recreation Service, state and local planning commissions, any federal landholding agency about providing recreational opportunities. Together the applicant and the agencies would develop a plan to provide for them. The applicant must also consult with the Departments of Interior and Agriculture to determine whether the site is on or near a wild and scenic river or a wilderness area, and to determine whether the site is under study for such designation. If the proposed facility is on or near either of these sensitive areas, permission to build a hydropower facility would be difficult to obtain.

The applicant must develop information on land management and aesthetics describing wetlands or floodplains located near the proposed facility to determine if impacts would result from development, and, if so, what mitigation measure would be taken. Other provisions of the section are to ensure that the land surrounding the project will be well-managed. To complete this section, the applicant would consult with federal agencies that manage federal lands at or near the site and state and local zoning and land management agencies.

The FERC licensing process has been mentioned repeatedly as an impediment to development (Brown and Buxton, 1979; IWR, 1979; Gladwell and Warnick, 1978; Brown and Wilson, 1979). The licensing process can be expedited, however, if the environmental issues are not significant and the applicant is familiar with all the intricacies of the permit process at the federal, state, and local levels. For example, a Lawrence, Massachusetts hydropower project adding power to an existing dam took 18 months for FERC to issue a license (Marker, 1979). FERC estimates that under its expedited procedures that the applications would now be processed in 9 to 12 months (GAO, 1980a). More important, the cost of meeting the environmental requirements of licensing is typically less than one percent of the total construction costs (Corps, 1979a; New York State Energy Research and Development Authority and Gibbs and Hill, 1980).

C. Environmental Legislation and Hydropower Development

The decade of the 1970s was the era of environmental awareness. Landmark legislation, beginning with NEPA, was passed in response to the public's interest in protecting the environment. The legislation, add to mandates provided by earlier statutes, gave the government powerful tools for environmental protection. This section provides an overview of national environmental legislation and policies. (Appendix G, describes all of the major environmental laws that affect hydropower).

The statutes that govern the construction of hydropower projects include primarily environmental control legislation (for example, permits issued under Section 401 of the Clear Water Act), and review and coordination legislation (for example, the Fish and Wildlife Coordination Act). Table 6-2 summarizes the federal legislation that affects hydropower development. In the table, responsibilities of various federal agencies are divided into four categories that, in effect, measure the degree of control afforded by each act. In addition, the table shows the relationship between the legislation and the key environmental factors identified in this environmental assessment. Except for land use, specific legislation provided coverage and protection for each of the environmental factors. Legislation affecting aquatic and terrestial ecology is particulary abundant.

The appropriate federal development agency is responsible for ensuring compliance with all relevant federal environmental statutes. For a nonfederal project, however, it is the license applicant who must develop the project in accordance with the federal and state regulations. If the applicant obtains an exemption from FERC licensing, only the state regulations will apply (including Economic Development Administration regulations that the states have been designated to enforce).

Many federal environmental laws and policies affect hydropower development in some way, three, in particular, have a significant effect on shaping the kind and amount of development that takes place. They are the following:

- Fish and Wildlife Coordination Act -- This act mandates that all federal agencies consider the impacts of their actions on fish and wildlife. It authorizes fish and wildlife protection agencies to review license applications and recommend mitigation. At present, mitigation for adverse fish and wildlife impacts is being recommended

Table 6-2

SUMMARY OF MAJOR ENVIRONMENTAL POLICIES
AFFECTING HYDROPOWER DEVELOPMENT

	Effect of Present Policy				Environmental Issues			
	Compliance Required For FERC License	Requires Fed. - State Permits	Authorizes Agency Review	Authorizes EIS[a]	Aquatic Ecology	Terrestrial Ecology	Land Use	Water Quality and Use
Archaeological and Historic Preservation Act			o	o			o	
Clean Air Act		o				o	o	
Clean Water Act Section 401	o	o			o			o
Clean Water Act Section 402		o			o			o
Clean Water Act Section 404		o			o	o	o	o
Coastal Zone Management Act		o[b]	o[b]		o	o	o	o
Endangered Species Act	o		o		o	o		
Energy Security Act					o	o	o	o
Federal Power Act	o				o	o	o	o
Fish and Wildlife Coordination Act			o		o	o		
Floodplain Management Executive Order 11988			o		o	o		o
National Environmental Policy Act			o		o	o	o	o
National Historic Preservation Act and Executive Order 11593			o				o	

Table 6-2 (continued)

	Effect of Present Policy				Environmental Issues			
	Compliance Required For FERC License	Requires Fed. - State Permits	Authorizes Agency Review	Authorizes EIS[a]	Aquatic Ecology	Terrestrial Ecology	Land Use	Water Quality and Use
National Trails System Act			o				o	
National Wetlands Policy, Executive Order 11990			o		o	o		o
Principles & Standards for Water Resources Planning			o		o	o	o	o
Resource Conservation and Recovery Act		o			o	o		o
River and Harbor Act of 1899	o	o		o	o	o	o	o
Wild and Scenic Rivers Act	o		o		o	o	o	o
The Wilderness Act			o		o	o	o	o

a. Sometimes required; depends on site conditions.
b. Required by some states.
c. Under this Act, a FERC license will not be required for some facilties with capabilities of 5 MW or less.

and implemented under interagency agreements reached as a result of this act (Natural Resources Law Institute, 1980; Schulthess, 1980).

- Endangered Species Act -- this act prohibits development of any project if it affects a significant portion of the critical habitat of an endangered species. The developer must prove to the satisfaction of the fish and wildlife protection agencies that no critical habitat is threatened. This act is the only existing law with authority to stop development for environmental reasons (Reynolds, 1980).

- The Wild and Scenic Rivers Act -- This Act has been characterized as the most serious obstacle to small dam development (Brown and Buxton, 1979). From an initial designation of eight rivers in 1968, amendments to the Act have added an additional 21 river segments. Proposed legislation would expand designated segments in 11 states and would designate approximately 20 additional segments for study and possible inclusion. Once a river is designated, it becomes an insurmountable obstacle for the developer. In addition, during a study period, no alteration of the environment is allowed, nor can FERC issue a license for any dam. FERC estimates that 12,750 MW of hydropower development have been precluded because of wild and scenic river designation.

For nonfederal hydropower, environmental protection provisions are part of the enabling legislation for hydropower projects. They are the following:

- Federal Power Act -- This act gives statutory authority to FERC to license facilities that sell electricity. This is the basis for all of FERC's environmental and recreational requirements. The license filing requirements (which include reporting substantial financial and organizational information) are considered to be time-consuming and burdensome by many developers. In addition, the Act gives the fish and wildlife protection agencies U.S. Fish and Wildlife Service, National Marine fisheries Service, and state fish and game departments) the authority to review projects and mandate mitigation for adverse impacts (Brown and Buxton, 1979).

- <u>Energy Security Act</u> -- This act, passed in June 1980, asks FERC to promulgate regulations that exempt some categories of hydropower facilities with capacities of less than 5 MW from some or all of the licensing requirements. Depending on the type of regulations proposed by FERC, this act could enable significant expansion of small-scale hydropower facilities. Environmental provisions of FERC licensing procedures, however, are not to be sacrificed for the sake of expediency.

Several statutes require that mitigation measures be proposed during the licensing process. The Federal power Act requires that fish passages be included in hydropower projects, if recommended. Compliance with the Fish and Wildlife Coordination Act may require purchase or designation of parkland or wetlands for their use as a wildlife habitat. Identifying and implementing mitigation measures can sometimes slow the development of the project (Gladwell and Warnick, 1978; IWR, 1979; Natural Resources Law Institute, 1980; Oliver, 1975; Schulthess, 1980). The cost of mitigating environmental impacts may help decide whether the federal government or a non federal applicant should develop a given hydropower site. Private entrepreneurs may choose to develop those sites at which environmental impacts can be mitigated most economically; the government may be able to develop those projects that are environmentally compatible but not cost effective for the private sector to undertake.

A key legislative initiative during the 96th session of Congress was the proposal for a National Energy Mobilization Board (EMB). The EMB would be a federal agency charged with expediting the development of high-priority energy development projects. The proposed bill appeared in several different versions; however, a key provision of the legislation was that the EMB could grant temporary waivers of existing federal laws to speed the development of energy projects (Energy Users Report, 1980). It was a clear expression of how far the nation would be willing to go to permit governmental promotion of energy development.

The proposal, however, was defeated by both houses of Congress. One of the major reasons cited for defeat was the unwillingness to tamper with environmental protection legislation. Although the EMB was directed more toward synfuels development than hydropower, it does suggest that the government is currently unwilling to abrogate the protection afforded by environmental legislation.

As a beneficial side effect of the EMB proposal, several federal agencies took steps to improve the procedure for compliance with their environmental regulations. Development of EPA's Consolidated Permit Program for five of its required permits and revisions to the procedures of the Department of Interior and the National Marine Fisheries Service were all completed in response to the possibility of an EMB and a general anti-regulatory mood throughout the country (Knight, 1980). Thus, the agencies showed that compliance with environmental protection laws could be made simpler without a legislative amendment (Commission on Federal Paperwork, 1977). More important, perhaps, the agencies demonstrated that effective management can maintain the protection offered by environmental legislation.

The Clean Air Act and the Wilderness Act will come before Congress for review in 1981. EPA officials have expressed worry that attempts will be made to cut the Clean Air Act and have proposed instead a careful and selective approach to amending the law (Inside EPA, 1980; Environment Reporter, 1980). The oil and gas industry is particularly interested in the Wilderness Act and has launched a major effort to ease its exploration rules (National Journal, 1980). Hydropower development in the western United States may be particularly affected if changes in the Act were to allow multiple use of land and water resources. If either law were to be changed significantly so as to reduce its present effectiveness, it could signal that other environmental laws that affect hydropower might soon receive more critical examination.

Nonetheless, Congress appears willing to support environmental programs, even if they add direct costs and an additional regulatory process to industry to control hazardous pollutants. In 1980, Congress continued efforts to expand the effectiveness of programs to control hazardous pollutants. The $1.6 billion superfund bill was passed in both Houses in December 1980, giving EPA the means to finance the cleanup of hazardous substance spills and inactive hazardous waste disposal sites (Environment Reporter, 1980).

An example of the possible future wave of legislation is the Pacific Northwest Electric Power Planning and Conservation Act enacted by Congress in 1980. In response to a projected serious shortfall in the supply of electricity in the region, this act lays out a detailed agenda for establishing and implementing a regional energy plan (BPA, 1981). It establishes a regional planning council that has representatives from each state and from BAP and gives BPA responsibility to meet the energy loads of customers and manage the regional energy supply while relying as much as possible on conservation and renewable sources of energy. Moreover, the council has two important environmental tasks: (a) it must establish a program to protect and enhance the fisheries resource of the Columbia river; and (2) it must provide a way in which environmental protection and energy needs of the region can be balanced. Thus, Congress has recognized that coordinated activity within a region offers promise for moving forward the goals of improved energy supply and enhanced environmental quality.

The actions of the 96th Congress suggest that wholesale changes in environmental legislation should be be anticipated. Because the laws enacted over the past 15 years have been supplemented by strong legal armor through case law and regulations, attempts to alter major environmental legislation may be difficult (National Journal, 1980). Any changes will probably involve only revisions to the regulations and procedures that agencies adopt to carry out their legislative mandate, and not fundamental changes to established principles of environmental protection.

The trend toward reducing license requirements will likely continue. Efforts to promote hydropower, primarily in the nonfederal sector, have concentrated on expanding the exemptions from FERC licensing requirements. The agency is considering publishing regulations that would allow it to exempt entire categories of applications from its licensing requirements, subject to existing environmental laws and policies. The Energy Security Act of 1980 authorizes FERC to reduce licensing requirements for hydropower facilities with capacities of up to 20 MW and the transition team of the new Administration recommended expanding exemptions to that level (Feine, 1980). Therefore, further efforts are likely to reduce the length of time it will take to obtain a FERC license and to ease requirements for developers when the risk of environmental damage is low.

The Public Utility Regulatory Policies Act of 1978 gave economic incentives and reduced regulatory requirements for facilities with capacities of less than 15 MW. Recently, some states--notably California, New Hampshire, and Massachusetts--passed similar legislation to stimulate development or to speed permitting for facilities. In he future, increased emphasis will no doubt focus on expediting state requirements.

The issue so prevalent during the 1930's and 1940's--whether the federal sector or the nonfederal sector should produce power--will probably stimulate significant debate. The nonfederal sector is expected to argue that it can develop a project much faster than the government (GAO, 1980); the federal sector will probably state it can best serve the public interest by adding the hydropower function to its projects that already serve other public purposes. However, a recent directive from the Corps' Office of Chief Engineers urged the District Engineers to assist private developers to construct and operate hydropower plants at Corps'dams (Schwaiko, 1980). The mood of Congress may tend toward private development in place of federal whenever possible.

CHAPTER 7

MITIGATION AND CUMULATIVE IMPACTS

A. Introduction

The preceding chapters of the report have discussed the environmental impacts of hydropower development and the environmental planning process. The success of the planning process in addressing the environmental impacts of hydropower largely depends on the availability and effectiveness of mitigation measures. This section generally defines mitigation and identifies the main mitigation issues, presents some mitigation techniques and their limitations, and reviews the level of implementation and overall effectiveness of the mitigation of impacts caused by hydropower development.

B. Mitigation

1. Defining Mitigation

In a strict sense, "mitigate" means to lessen adverse effects. Within the context of environmental impacts resulting from hydropower or other water resource development, the term, "mitigation," is considered in a larger sense as summarized by Jahn (1979) to include: (1) avoiding the adverse impacts altogether by not taking a certain action or parts of an action: (2) minimizing impacts by limiting the degree or magnitude of the action and its implementation: (3) rectifying the impact of repairing, rehabilitating, or restoring the affected environment; (4) reducing or eliminating the impact over time by preservation and maintenance operations during the life of project, and (5) compensating for the impact by replacing or providing substitute resources or environments. Although this broad class of actions is more properly a description of environmental planning, it is used here as a definition of mitigation to capture the important issues under this topic.

2. Main Issues

Chapter 3 sketched the spectrum of environmental effects from hydropower. The most direct and critical of those effects are on fish and wildlife resources. Similarly, although legislation requires the planning process to address an extensive realm of environmental issues, consideration of fish and wildlife, in response to the Fish and Wildlife Coordination Act, is a prominant concern. Thus, the mitigation of impacts on fish and wildlife is considered here to be the most important topic of mitigation.

C. Selected Mitigation Techniques

A complete review of available techniques to mitigate impacts on fish and wildlife is beyond the scope of this report.[1] In Chapter III, engineering techniques were discussed that can be incorporated into the design (e.g., fishways, diversion screens) or the operation of the facility. This section summarizes other common measures available to mitigate some of the most common impacts. Following is a brief description and assessment of their effectiveness and cost.

1. Hatcheries and Spawning Beds

Fish hatcheries are a popular mitigation measure to replace or supplement natural spawning. By controlling environmental conditions within acceptable limits in a hatchery, successful egg incubation and survival of fry can be greatly increased over natural conditions, such that a few fish can supply enough eggs and sperm for hundreds of thousands of fry. Vertical incubators having stacks of trays are provided with fresh water. Once the eggs hatch, the fry are transferred to shallow rearing ponds (for warmwater fish) or circular or rectangular raceways (for coldwater fish). Because hatcheries need large volumes of high quality water, good sites are limited.

---

[1]The reader is referred to the Nelson et al. (1978) for a comprehensive review.

Generally, hatcheries are very successful, but very expensive. A review of six hatcheries by U.S. Fish and Wildlife Service (1978) found amortized capital and operating costs to range from $20 to $27 per pound of fish produced annually.

Losses in natural spawning may occur when construction or development takes place in a river basin. To mitigate these losses, either the natural channels that have become clogged with sediment must be cleared or artificial channels layered with gravel put in place. Artificial spawning channels are generally more effective than natural beds. Although the Forest Service has had limited success with a machine to dislodge and collect silt from natural spawning beds, Mih and Bailey (1979) believe that a modified version of this machine has the potential to economically and effectively clean silt-laden stream channels. The costs for this type of mitigation, although less than hatcheries, is still substantial.

2. Instream Flow Requirements

Some of the most significant impacts of hydropower development are caused by altered streamflows below the dam. Instream flow requirements are often used to define acceptable lower limits of flow to maintain water quality, fisheries, and other beneficial uses.

Minimum flow requirements to maintain water quality are generally lower than those needed to maintain fisheries. Section 102(b) of the Clean Water Act prohibits using storage and water releases as a substitute for adequate waste treatment. Base flows are sometimes used by state or federal agencies to allocate waste loads; however, such flows are commonly based on worst-case conditions such as the 7-day, 10-year low flow ($7Q^{10}$).

Fish maintenance flows are typically based on historic flows and the "target" species, although few general rules and methodologies are available. In New England, the U.S. Fish and Wildlife Service recently suggested a universal minimum flow standard for summer months of 0.5 cubic feet per second per square mile of drainage (Knapp, 1980). In the western states, the "Montana method" is accepted as a general standard for estimating fish-maintenance flows. Ten percent of mean annual flow is considered to provide a minimum short-term survival habitat; 30 percent is considered necessary for maintaining an adequate fishery (Tennant, 1976). The Cooperative Instream Flow Service Group of the U.S. Fish and Wildlife Service in Fort Collins, Colorado, has developed a more sophisticated methodology that employs computer simulation to assess fish-maintenance flows for a particular stream reach (Stalnaker and Arnette, 1976).

The primary problem with using instream flow requirements to mitigate environmental impacts is that they directly compete with other demands for water, including hydroelectric generation for peaking power. Another source of limitation on water allocations for fish and wildlife are water laws in the western states. Because some states do not recognize instream flow protection as a beneficial use, water cannot be appropriated, reserved, or water rights purchased for fish and wildlife needs (Nelson et al., 1978b). Even when such flows are recognized as a beneficial instream use, they can still be legally challenged. Several dozen legal and administrative strategies, based on federal and state laws and regulations, have been identified for negotiating minimum instream flows. Recommendations by fish and wildlife agencies for fish-maintenance flows have been accepted less often than have other mitigation measures. Even in those cases where minimum flow requirements were accepted, they were often violated (Nelson et al., 1976, cited in Horak, 1979).

One engineering technique that may aid in correcting the problem of fluctuating stream flow is the use of hydraulically controlled, automatic spillway gates. They are not feasible for all projects, but they are being tried at Angostura Dam in South Dakota. The gates open and close in response to the surface level changes of the reservoir (Nelson et al., 1978a). At present, the only other mitigating technique for reservoir fluctuations is manual control of operation. This can reduce environmental problems, but flexibility in power generation undoubtably is sacrificed.

3. Wildlife Habitat Replacement

Fish and wildlife agencies often require land acquisition to help compensate for wildlife habitat flooded in the creation of a reservoir. Land adjacent to streams (riparian land) is often valuable wildlife habitat with lush vegetation. Because the new reservoir shoreline and replacement land lack the same rich alluvial soil as the floodplain, they cannot support the same vegetation and associated habitat. Many measures are used to increase the wildlife carrying capacity of acquired lands. Examples include fencing to exclude livestock, the creation of ponds for waterfowl, irrigation to support riparian vegetation, selective clearing to create an "edge" environment, planting of food and cover, and the use of dredge spoils and dikes to create additional wetlands.

If fully implemented, land acquisition (including purchase, easement, and leasing) generally is an effective measure to mitigate wildlife losses. In some cases, suitable replacement land is unavailable. In other cases, as discussed later in this section, this measure is frequently not implemented because of a lack of funding or because of other institutional problems.

D. Implementation

The effectiveness of mitigation measures is limited not only by technical drawbacks, but also by institutional problems. Horak (1979), for example, summarized six research projects (Davis et al., 1973, Horak 1974, Horak 1973, Nelson et al., 1978b) that analyzed the effectiveness of nearly 600 fish and wildlife mitigation measures recommended at 146 water resource projects sponsored by the Corps, Bureau of Reclamation, and other federal agencies. Most (87 percent) of the measures agreed to by the sponsoring agency were eventually implemented, but the level of acceptance and implementation largely depended on the type of measure proposed. About one quarter (26 percent) of the recommended measures were rejected by the sponsoring agency. Most of the measures (63 percent) were agreed to without modification. The remaining measures (11 percent) were accepted with some modification. Requests for minimum flows and/or controls on reservoir fluctuation and requests for land acquisition were least likely to be accepted and implemented. Restrictions on reservoir releases directly conflicted with other project objectives and therefore were unpopular with sponsoring agencies. Nelson et al. (1976) found that minimum flows agreed to by the agencies at 30 projects were violated an average of 85 days per year. Half of the requests for land acquisition were rejected; funding limitations and state and local conflicts were the primary drawbacks. State and local interests often oppose land acquisition because of lost property taxes, cost-sharing requirements, or the need for condemnation.

Although they were extremely expensive, requests for fish hatcheries and rearing ponds were almost unanimously accepted. Other fish control and enhancement measures, such as barrier dams, fish screens, and stocking were also accepted. All of these measures were highly visible to the public and placed minimal restrictions on reservoir construction or operation.

Wood and Swift (1979) reviewed the formulation and implementation of fish and wildlife conservation plans for ten Corps projects in the Southeastern United States. Their primary purpose was to develop an evaluation model, but their work also provided some information on the implementation of mitigation measures at Corps' projects. Of the ten projects, four had soundly conceived wildlife plans; the plans for eight of the projects were well-coordinated and compatible; five of the plans were developed with national, regional, and local level teamwork; five of the projects had strong support and overcame opposition, and effort was sustained for seven of the projects; six of the wildlife plans were successfully implemented. A total of 256,000 acres of land was recommended for wildlife purposes; about half; 129,000 acres, was actually received.

The U.S. Fish and Wildlife Service (Gard, 1979) has reviewed all Corps' projects in the lower Mississippi River Valley in which the U.S. Fish and Wildlife Service made significant mitigation recommendations. Fifty years ago, this region contained 25 million acres of forested wetlands, which supported perhaps the most diverse and productive fish and wildlife resources in North America. Today, approximately 3 million acres remain, but are being cleared at a rate of up to 300,000 acres per year. The majority of the conversion from forested wetlands to farmland was made possible by massive federal flood control projects. To offset some of the 2,300,000 acres of wildlife habitat lost from Corps' projects, the Fish and Wildlife Service recommended acquisition of 610,740 acres of forest land (27 percent of the amount lost). Congress authorized acquisition of 182,765 acres (eight percent of the amount lost), but only 36,683 acres (less than two percent of the amount lost), have actually been purchased. The degree of implementation of structural requests was similarly low; only 8 of 43 structural recommendations were implemented.

The Sport Fishing Institute (Norville, Martin, and Stroud, 1979) evaluated the accuracy of impacts on fish and wildlife projected in planning reports for Corps' projects. Of the 78 projects with adequate pre-evaluation of fish and wildlife conditions, 35 received some post-evaluation of wildlife conditions; and 14 received post-evaluation for both fish and wildlife. Detailed studies have been completed on ten projects. In eight, the Fish and Wildlife Service recommended land acquisition for wildlife, totalling more than 16,000 acres. Of these, three requests for a total of nearly 10,000 acres were rejected by the Corps, two requests (3,300 acres) were not implemented because the state did not act; one request (3,400 acres) was withdrawn by the Fish and Wildlife Service; funding is pending for one request (1,100 acres); and only one request (2,800 acres) was implemented. Measures to enhance wildlife habitat were seldom proposed and less frequently implemented. Agreement of the wildlife population estimates between pre - and post-evaluation studies were erratic.

E. Conclusions About Mitigation

Several reasons were posed by these researchers and others to explain why mitigation efforts are often ineffective. Some of the key reasons expressed are:

- Fish and wildlife considerations are not incorporated early in the planning process (Short and Schamberger, 1979; Dziedzic and Oliver, 1979; Armacost, 1979; Voigt and Nagy, 1979; Rappoport, 1979).

- Implementation of mitigation measures lags behind overall project implementation and there is little commitment to monitor mitigation (Short and Schamberger, 1979; Horak, 1979; Armacost, 1979; Voigt and Nagy, 1979).

- Political opposition and lack of funding blocked mitigation (Dziedzic and Oliver, 1979; Wood and Swift, 1979; Voigt and Nagy, 1979; Gard, 1979).

- Methodologies to quantitatively predict and evaluate impacts and to assess the effectiveness of mitigation were not used in the past (Short and Schamberger, 1979; Rappaport, 1979; Prosser, Martin, and Stroud, 1979).

- Technical solutions to some problems are unavailable or untested (Dziedzic and Oliver, 1979).

Efforts have been made to remedy most of these issues, so that more successful mitigation is possible in the future, although these issues are likely to remain to some degree. The intent of the Fish and Wildlife Coordination Act and the National Environmental Policy Act is to foster early planning for fish and wildlife and other environmental concerns. However, to do so requires overcoming antagonism between those who construct and those who protect. President Carter's Water Policy Reform Message of 1978 partially addressed the second issue by requiring "that mitigation funding and implementation be provided concurrrently with project appropriation and construction" (Voigt and Nagy, 1979).

Although the U.S. Fish and Wildlife Service (1979) has developed standardized "Habitat Evaluation Procedures" (HEP) for quantitatively measuring impacts, technical solutions to mitigate lost wildlife habitat are lacking. Thus, recent mitigation efforts have been less successful for wildlife than for fish. Although some measures may be taken to offset the loss of wildlife habitat by increasing the productivity of other land, this issue points out the inevitability of at least some trade-offs between hydropower development and environmental quality.

The lack of funding for mitigation is a major problem. Stated simply, those who advocate mitigation have no money to pay for it. Post-evaluation and monitoring also suffer from lack of funding. Generally, fish and wildlife protection agencies are strapped for funds to even evaluate probable impacts, much less implement mitigation for them. The burden has always been placed on the developer to take action, although he receives no tangible economic benefit from doing so.

There are several possible approaches to this problem. First, one could demonstrate some concrete benefits from the mitigation such as: better public acceptance of the project and thus of the developer; greater influx of visitors for recreation (assuming the developer plans to provide recreation facilities); or receiving quicker approval for the project and thus saving money on interest payments (by becoming operational and revenue-producing sooner). Second, the developer or operator could be allowed to pass the cost of mitigation on to the consumer. At present, this is not permissible in most cases. Third, the Corps or other federal agency could take responsibility to implement mitigation for the federal and nonfederal developer alike. In this way, the public would in effect be subsidizing the mitigation--or in other words, the protection of a public resource.

F. Cumulative Impacts

The impacts of a hydropower plant are not restricted to the project site, but extend to other parts of the river and the watershed. Because project-by-project mitigation is not fully effective, the cumulative impact of several hydropower and other water resource developments can severely affect a region's resources, particularly fisheries, water supply, water quality, white-water recreations, and wildlife. As the level of development in a region increases, environmental impacts must be viewed in a cumulative sense. This section focuses on two river basins in geographically diverse regions, but with similar problems of cumulative impacts. The first describes the Connecticut River Basin and some models that are being developed to predict cumulative impacts. In the second section, the Columbia River Basin is described along with some potential indices that could be used in planning additional hydropower development in the basin.

1. The Connecticut River Basin

New England was the first region in the country that was developed with hydropower. The impact of extensive development in the region has largely spoiled the water quality of major rivers, reduced streamflows to levels that are harmful to fish and wildlife, and nearly eliminated the region's anadromus fish population.

The Connecticut River Basin is the most heavily developed basin for hydropower in New England. Although it is only 11,000 square miles, it contains over 700 dams, almost 600 MW of conventional hydropower generating capacity, and 1,600 MW of pumped storage capacity. Most of the hydropower capacity is used for peaking power production. Hydropower facilities are hydraulically coordinated along the Connecticut and Deerfield Rivers by large upstream reservoirs. The cumulative impacts of hydropower development in the Connecticut River Basin (Federal Power Commission, 1976) have raised significant concerns regarding the maintenance of minimum streamflow, adequate water quality, available spawning grounds, and fish passage for anadromous American shad and Atlantic salmon.

The Connecticut River Basin is representative of the types of hydropower impacts likely to be found in the Northeast, and has been the focus of efforts to assess cumulative impacts in that region. The New England River Basin Commission (1979), the U.S. Fish and Wildlife Service (1979) and the FERC

(Shuster, 1976) are actively involved in studying the cumulative impacts of hydropower development.

Although research on the Connecticut River Basin holds the promise for accurately predicting cumulative impacts and directing future actions to enhance the environmental quality of the basin, it also illustrates some of the difficulties in assessing cumulative impacts. Institutional problems limit the use of sophisticated technical models. Specifically, an understandardized, discontinuous data base, outdated policy guidance, and inadequate funding hamper the use of models for interstate basin planning. Technically, a single, all-encompassing cumulative-impacts basin mode is not considered realistic. Instead, four models--a water-allocations model, a peak-flow runoff model, a low-flow routing model, and a water quality model are judged capable of enabling the analyst to address the central questions that arise from resource conflicts (New England River Basins Commission, 1979).

Other regions of the country can expect institutional and technical problems similar to those encountered with the Connecticut River. In fact, the availability of an adequate data base, modeling capability and funding are likely to be even more limiting in most regions. However, as will be shown for the Columbia River Basin, simple indices of major changes in the characteristics of a river caused by hydropower development can give a reasonable indication of cumulative impacts.

2. The Columbia Basin

The Columbia River Basin, including the Snake River, is more developed with hydropower than any other region in the nation. Hydropower facilities (164) plants account for more than 22,000 MW of generating capacity in the Columbia Basin; that amounts to 35 percent of the nation's total hydropower capacity. This basin still has a tremendous amount of additional potential (IWR, 1979). Because the Columbia Basin is less urbanized than the Connecticut River Basin, and because runoff is higher in the Columbia Basin, water supply and water quality in the Columbia Basin are less important issues. The Columbia's anadromous fishery, however, is more valuable than the Connecticut's.

Although a loss of wildlife habitat is a major concern in the region[1] (Oliver, 1975), the loss of anadromous fish from hydropower development represents the most significant cumulative impact.

As described in the previous chapters, hydropower plants have blocked access to spawning grounds in the upper reaches of the Columbia, Snake, Deschutes, and Willamette Rivers (Figure 7.1). Supersaturation of atmospheric gas, caused by spillway flows that plunge deep beneath the surface of the river, creates embolism in fish. Long, slow-moving reservoirs slow the downstream migration of juveniles. Storage reservoirs also impede downstream migration by capturing the spring freshet. Turbine passage is probably the major cause of the lower anadromous fish populations in the Columbia Basin (Raymond, 1979, cited in Ebel, 1979).

From 1880 to 1920 an average of between 30 and 40 million pounds of commercial salmon and steelhead trout were caught from the Columbia River annually (Pacific Northwest River Basins Commission, 1971). Although Swan Falls, and Lower Salmon dams were built on the central Snake River in the early 1900's, the first major dam construction to affect the anadromous fish population on the Columbia Basin were three major federal projects built during the Great Depression. Although only 51 feet high, Rock Island dam in Central Washington, constructed from 1930 to 1933, created a reservoir 21 miles long. Started in 1933, Bonneville dam, about 20 miles upstream from Portland, is roughly the same height as Rock Island, but, owing to the gentle terrain, the reservoir is 45 miles long. Fishways were installed at both Rock Island and Bonneville, but the largest project, Grand Coulee Dam, stated in 1934 and finished in 1941, blocked access to anadromous fish spawning grounds

---

[1]More than 1.2 million acres of land have been inundated by reservoirs in the Pacific Northwest (DOE, 1980).

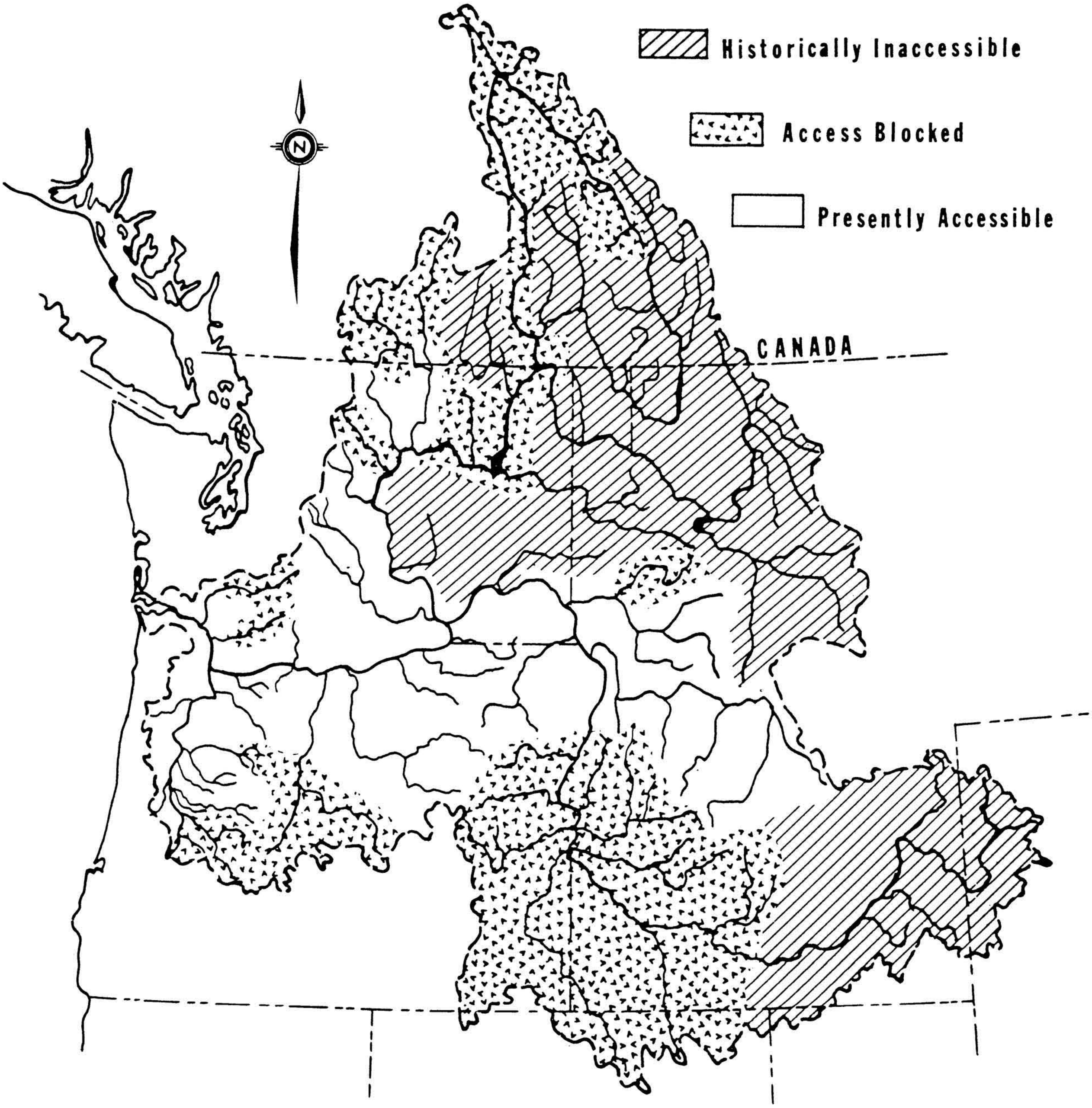


Figure 7.1 MAP OF THE COLUMBIA RIVER SYSTEM SHOWING AREA ACCESSIBLE TO ANADROMOUS FISH HISTORICALLY AND IN 1970.

Source: Oregon Department of Fish and Wildlife and Washington Department of Fisheries, 1976.

in the upper Columbia. The dam, 343 feet high, created a reservoir 150 miles long and provided more than 2,000 MW of hydroelectric capacity. Following the construction of the three projects, the commercial salmon and steelhead trout catch in the Columbia dropped to approximately 20 million pounds annually.

The next period of major dam construction on the Columbia and Snake Rivers followed the completion of the Second World War and continued through the early 1970s. During this period, the Columbia and Snake Rivers were transformed into a series of impounded pools. Nearly 800 miles of river were transformed into reservoirs, producing almost 20,000 MW of electricity. Although fishways were provided at most plants, Hells Canyon dam blocked fish passage to the central Snake. Mortality from turbine passage and nitrogen narcosis greatly reduced the survival of juveniles migrating downstream. During normal flow and high-flow years, smolt survival is between 30 and 45 percent. Survival is as low as 5 to 19 percent during low-flow years (Committee on Fishery Operations, 1977 cited in Nelson et al., 1978). The number of returning salmon dropped to an all time low in 1973, nearly eliminating fish runs on the Snake (DOE, 1980).

As part of this study, some indices are proposed that may foster a better understanding of development in a watershed and allow one to determine when a particular watershed is approaching a threshold beyond which severe environmental impacts occur. A discussion of the proposed methodology for assessing cumulative impacts appears in Appendix H. The Columbia River was selected for testing some of the proposed indices, because substantial data have been published about its changing water resource characteristics as additional hydropower installations have been constructed.

The historical drop in commercial salmon and steelhead trout catch on the Columbia correlates well with a few simple indices of changes in the river system caused by hydropower development (Figure 7.2). Fish catch, however, is not the best measure of impact on the fishery because catch also depends on the amount of commercial and sport fishing that takes place. Irrigation diversions and poor land management practices have adversely affected the

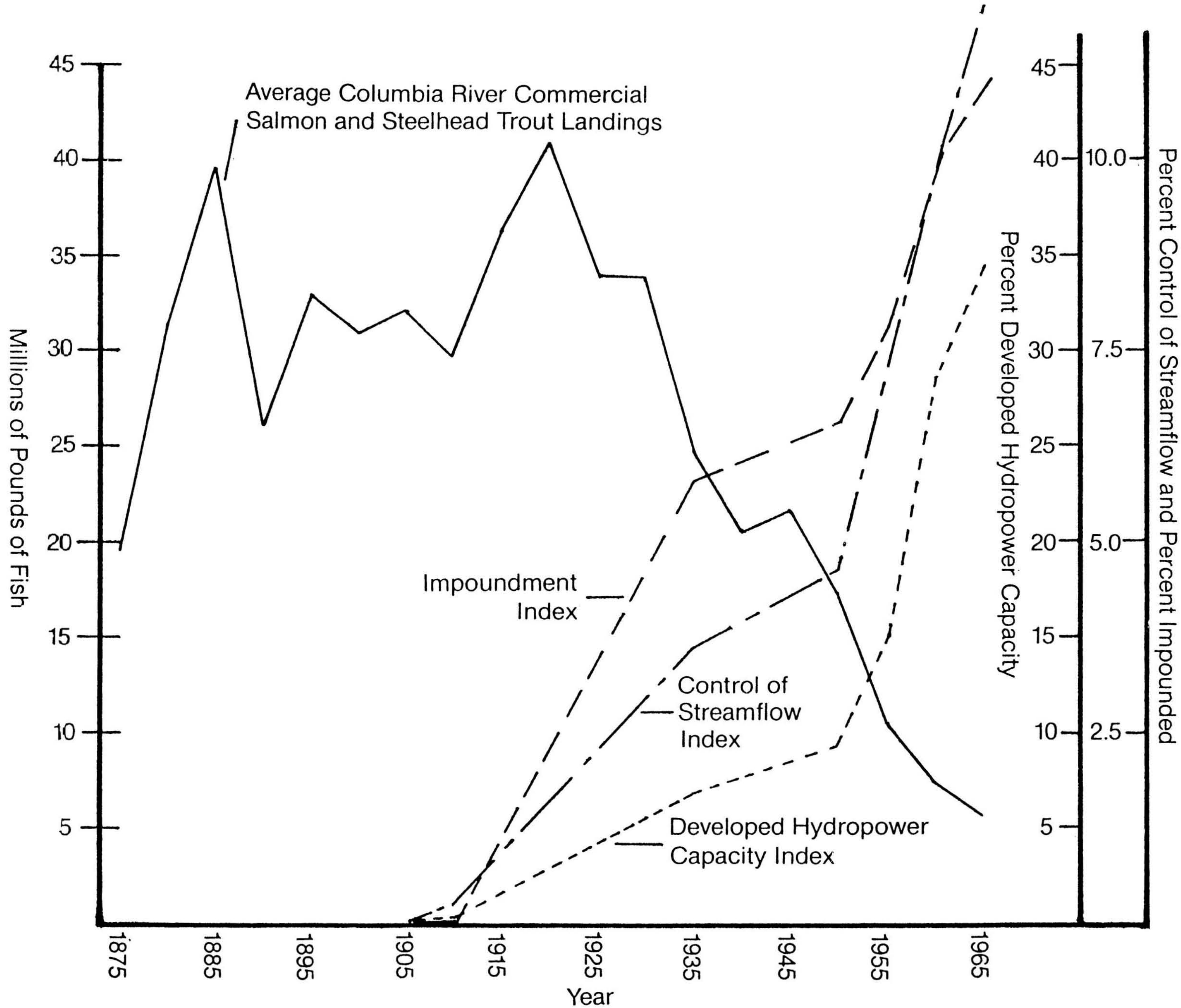


Figure 7.2 COMPARISON OF COLUMBIA FISH CATCH AND CUMULATIVE IMPACT INDICES

Columbia's anadromous fishery; however, hydropower development is clearly a major factor in explaining the tremendous decline in catch, which is, nontheless, a good, if not perfect, indicator of the condition of the fishery.

The first index, the percentage of developed hydropower capacity, is simply the total developed capacity compared with the theoretical maximum potential. This measure is strongly correlated ($r = -.93$) with pounds of fish caught in the Columbia between 1895 and 1965.

The second index is the combined storage capacity of the reservoirs on the Columbia and Snake Rivers divided by the average annual streamflow at the mouth of the Columbia. This indicates the degree to which streamflow can be regulated, including reducing spring freshnets. Again, the correlation with fish catch is very strong ($r = -.96$).

The final index is the cumulative length of impounded water divided by the total length of the river. This index reflects the change in the river to a more lake-like environment and yields the best correlation ($r = -.97$) with pounds of fish caught.

Enormous sums of money have been spent to help maintain and improve the Pacific Northwest's anadromous fishery. More than 76 fish hatcheries and 58 rearing ponds and spawning channels have been constructed in the region (Pacific Northwest River Basins Commission, 1971). Spillway deflectors have been retrofit on large dams, greatly reducing gas supersaturation. Turbine bypass systems, capable of diverting 70 to 80 percent of the fish entering turbine intakes, have been designed and installed. Fish are collected and transported upstream around dams. Scanning sonar has been used to locate schools of downstream migrating juveniles so that turbine intakes can be closed for two hours, allowing the fish to pass over the dam with the increased spillway flows (Ebel 1979). As evidenced by the Lower Snake Compensation Plan (see Armacost, 1979), the Bumping Lake Enlargement Project (DOI, 1976), and recent passage of a Pacific Northwest power planning bill (S 885), which calls for preparation of a program to protect fish and wildlife, impacts are being addressed in a broader perspective, rather than simply on a project-by-project basis. Despite these efforts and recent evidence of increased survival rates, the cumulative impact of hydropower development has permanently and severely reduced the anadromous fishery resource in the Columbia River Basin. Cumulative impacts on fisheries, and other resources, are likely to be increasingly important environmental issues as the level of hydropower development rises in many regions of the country.

BIBLIOGRAPHY
(By Chapter)

Chapter 2

Allis-Chalmers, 1980. "Standardized Hydroelectric Generating Units."

Bell, Milo C. and Hildebrand, Stephen G., October 1979. "Fish Passage and Small Hydroelectric Technology: A State of the Art Review." Presented at Waterpower 79: An International Symposium on the Potential of Small-Scale Hydropower. Washington, D.C.

Chapus, Edmond E. and Chourchi Haddad, September 1978. "Bulb Units for Low-Head Hydroelectric Generation." in Low Head Hydro: An examination of an Alternative Energy Source. Idaho Water Resources Research Institute. Moscow, Idaho.

Clay, C.H., January 1961. Design of Fishways and Other Fish Facilities. The Department of Fisheries of Canada. Catalog No. FS 31-1961/1.

Ebel, Wesley, 1979. "Effects of Hydropower Projects on Fish Populations" in Hydropower: A National Energy Resource, proceedings of a conference sponsored by the Engineering Foundation in cooperation with the U.S. Army Corps of Engineers. March 11-16, 1979. Fort Belvoir, Virginia.

Engineering News Record, 1980. "Baffles Boost Reservoir Oxygen Levels."

Federal Power Commission, 1976. "Report on Significant Interrelationships between Electric Power Generation and Natural and Developed Resources in the Connecticut River Basin." U.S. Government Printing Office. Washington, D.C.

Linsley, Ray K. and Joseph B. Franzini, 1972. Water-Resources Engineering. McGraw-Hill. New York, New York.

Nelson, R. Wayne, Gerald C. Horak, and James E. Olson, October 1978. "Western Reservoir and Steam Habitat Improvements Handbook." Enviro Control, Inc. Prepared for the Western Energy and Land Use Team, Office of Biological Services, Fish and Wildlife Service. FWS/OBS-78/56. Fort Collins, Colorado

U.S. Fish and Wildlife Service, 1961. "Design of Fishways and Other Fish Facilities." U.S. Government Printing Office. Washington, D.C.

U.S. Fish and Wildlife Service. Office of Biological Services. 1977a. "Review of Hydroelectric Power Projects Licensed by the Federal Power Commission." U.S. Government Printing Office. Washington, D.C.

U.S. Fish and Wildlife Service, 1977b. "Features of Hydroelectric Facilities and Their Impacts on Fish and Wildlife Resources." U.S. Government Printing Office. Washington, D.C.

U.S. Army Corps of Engineers, July 1974. "Major Steps in Corps of Engineer Water Resources Development." Office of the Chief of Engineers. Washington, D.C.

U.S. Army Corps of Engineers, Institute for Water Resources, July 1975. "Hydroelectric Power Potential at Corps of Engineers Projects." Fort Belvoir, Virginia.

U.S. Army Corps of Engineers, July 1979a. "Feasibility Studies for Small-Scale Hydropower Additions: A Guide Manual." Fort Belvoir, Virginia.

U.S. Army Corps of Engineers, September 1979b. "Hydropower." Office of the Chief of Engineers, Washington, D.C.

U.S. Army Corps of Engineers, October 1980. Computer Data files for the National Hydropower Study. Hydrologic Engineering Center. Davis, California.

U.S. General Accounting Office, January 11, 1980a. "Hydropower--An Energy Source Whose Time Has Come Again." U.S. Government Printing Office. Washington, D.C.

U.S. General Accounting Office, April 1, 1980b. "The Rural Energy Initiative Program for Small Hydropower--Is it Working?" U.S. Government Printing Office. Washington, D.C.

U.S. Senate, June 19, 1980. "Energy Security Act," Conference Report No. 96-824. 96th Congress, Second Session. U.S. Government Printing Office. Washington, D.C.

U.S. Water and Power Resources Service, July 1980. "Report on Assessment of Small Hydroelectric Development at Existing Facilities." Department of Interior. Washington, D.C.

Bell, Milo, February 1973. "Fisheries Handbook of Engineering Requirements and Biological Criteria." U.S. Army Corps of Engineers, North Pacific Division. Portland, Oregon. NTIS Report No. AD/A-006 404. Springfield, Virginia.

Brookhaven National Laboratory, March 1976. "Energy Model Data Base (User Manual)." BNL-19200. Brookhaven, New York.

Childress, Don A. and Robert L. Eng, 1979. "Dust Abatement on Canyon Ferry Reservoir, Montana" in the Mitigation Symposium. Report RM065. Rock Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Ebel, Wesley, March 1979. "Effects of Hydroelectric Projects on Fish Populations." in Hydropower: A National Energy Resource. Institute for Water Resources. Fort Belvoir, Virginia.

Ebel, Wesley and M. Raymond, July 1976. "Effects of Atmospheric Gas Supersaturation on Salmon and Steelhead Trout on the Snake and Columbia Rivers." National Marine Fisheries Review. Washington, D.C.

Hannon, Herbert H., 1979. "Chemical Modification in Reservoir Regulated Streams." in The Ecology of Regulated Streams. J. V. Ward and J. A. Stanford, Editors. Plenum Press. New York, New York.

Hittman Associates, 1975. "Environmental Impacts, Efficiency and Cost of Energy Supply and End Use." Volume I. PB-238784. Volume II. PB-239159. National Technical Information Service. Springfield, Virginia.

Holden, Paul B., 1979. "Ecology of Riverine Fishes in regulated Stream Systems with Emphasis on the Colorado River." in The Ecology of Regulated Streams. J. V. Ward and J. A. Stanford, editors. Plenum Press. New York, New York.

Holdren, John P., Kirk R. Smith, and Gregory Morris, 1979. "Energy: Calculating the Risks (II)." Science, Volume 204, pp. 564-568.

Inhaber, Herbert, February 23, 1979. "Risk with Energy from Conventional and Nonconventional Sources." Science, Volume 203, pp. 718-723.

Kash, D.E. et al., 1973. "Energy Under the Oceans: A Technology Assessment of Outer Continental Shelf Oil and Gas Operations." University of Oklahoma Press. Norman, Oklahoma.

Bonneville Power Administration, July 1977. "Draft Environmental Statement. The Role of the Bonneville Power Administration in the Pacific Northwest Power Supply System." Part 1, the Regional Electric Power Supply System; Part 2, The Role of the Bonneville Power Administration. Portland, Oregon,.

EDAW, Inc., 1978a. "Kings River Hydroelectric Project Pine Flat Power Plant." FERC Exhibit W. San Francisco, California.

EDAW, Inc., 1978b. "Hydroelectric Development in North Fork Stanislaus River." FERC Exhibit W. San Francisco, California.

EDAW, Inc., 1978c. "Dike Hydroelectric Project, Snake River, Idaho." San Francisco, California.

EDAW, Inc., 1978d. "Dryden Hydroelectric Project, Wenachee, Washington." San Francisco, California.

EDAW, Inc., 1979a. "South Fork American River Development, Upper Mountain Project." FERC Exhibit W. San Francisco, California.

EDAW, Inc., 1979b. "Lucky Peak Hydroelectric Project, Boise, Idaho." San Francisco, California.

EDAW, Inc., 1979c. "Swan Falls-Guffey Hydroelectric Project, Snake River." San Francisco, California.

EDAW, Inc., 1980a. "Wiley Hydroelectric Project, Snake River, Idaho." San Francisco, California.

EDAW, Inc., 1980b. "Application for License: Project No. 2757, Juniper Cross-Mountain Project, Exhibit W - Enviornmental Report." San Francisco, California.

Environaid, October 1975. "A Hydrologic Reconnaissance of The Sustina River Below Devil's Canyon." Prepared for U.S. Army Corps of Engineers, Anchorage, Alaska.

Fennerman, Nevin, 1931. "Physiography of the Western United States." McGraw-Hill. New York, New York.

Fennerman, Nevin, 1931. "Physiography of the Eastern United States." McGraw-Hill. New York, New York.

Geraghty, James J. et al., 1973. Water Atlas of the United States. Water Information Center. Port Washington, New York.

Graf, William, February 1980. "The Effect of Dam Closure on Downstream Rapids." Water Resources Research. Volume 16, Number 1. pp. 129-136.

Greak Lakes Basin Commission, 1976. "Great Lakes Basin Framework Study." Ann Arbor Michigan.

Hunt, Charles, 1967. Physiography of the United States. W. H. Freeman and Co., San Francisco, California.

Hunt, Charles, 1967. Natural Regions of the United States and Canada. W. H. Freeman and Co., San Francisco, California.

Loar, J.M., L.L. Dye, R.R. Turner and S.G. Hildebrand, July 1980. "Analysis of Enviornmental Issues Related to Small-Scale Hydroelectric Development, I. Dredging." Publication No. 1565. Oak Ridge National Laboratory. Oak Ridge, Tennessee.

Missouri Basin Inter-Agency Committee, December 1971. "The Missouri River Comprehensive Framework Study." Kansas City, Missouri.

National Electric Reliability Council, April 1978. "1978 Annual Report." Princeton, New Jersey.

National Electric Reliability Council, April 1978. "1979 Annual Report." Princeton, New Jersey.

National Electric Reliability Council, April 1978. "1980 Summary for the Regional Reliability Councils." Princeton, New Jersey.

New England River Basins Commission, June 1978. "Merrimack River Basin Overview." Boston, Massachusetts.

New England River Basins Commission, June 1979a. "Thames River Basin Overview." Boston, Massachusetts.

New England River Basins Commission, December 1979b. "Kennebec River Basin Overview." Boston, Massachusetts.

New England River Basins Commission, March, 1980. "Piscataqua and New Hampshire Coastal River Basins Overview." Boston, Massachusetts.

Ohio River Basin Commission, 1978. "The Ohio Main Stem Comprehensive Coordinated Joint Plan." Cleveland, Ohio.

Shaw, Gaylord, April 1978. "The Search for Dangerous Dams - A Program to Head Off Disaster." Smithsonian. Volume 9, Number 1.

Latham, H.S., and J.M. Verzuh, September 1971. "Reducing Hazards to People and Animals on Reclamation Canals." U.S. Bureau of Reclamation. Report No. REC-ERC-71-36. Cited in Nelson et al., 1978.

Loar, J.M. L.L. Dye, R.R. Turner, an S. G. Hildebrand, July 1980. "Analysis of Environmental Issues Related to Small-Scale Hydroelectric Development, I. Dredging." Publication No. 1565. Oak Ridge National Laboratory, Oak Rridge, Tennessee.

McBride, J.P., R.E. Moore, J.P. Witherspoon,, and R.E. Blanco, December 1978. "Radiological Impact of Airborne Effluents of Coal and Nuclear Plants." Science. Volume 202, Number 4372.

Miller, Andrew C., July 1979. "Development of Wildlife Compensation Features at Water Resource Projects." in The Mitigation Symposium. Report RM-65. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Nelson, R.W., G.C. Horak, and J.E. Olson, Ocotober 1978. "Western Reservoir and Stream Habitat Improvements Handbook." Report No. FWS/OBS-78/56. Office of Biological Services, U.S. Fish and Wildlife Service, Ft. Collins, Colorado.

North Carolina Department of Commerce, October 1979. "Wood for Energy and Its Impact in Western North Carolina, Volume III." Raleigh, North Carolina.

Office of the Chief of Engineers, no data. "Recommended Guidelines for Safety Inspection of Dams." Department of the Army, Washingotn, D.C.

Oliver, Wendell H., 1975. "Wildlife Problems Associated with Reservoirs for Electrical Power Generation." Paper presented at Western Association of State Game and Fish Commissioners. 54th Annual Conference. Albuquerque, New Mexico.

Szulha, Adam T. et al., October 1979. "Analysis of Environmental Impacts of Water Level Fluctuation in Reservoirs at Hydroelectric Sites." Oak Ridge National Laboratory. Oak Ridge, Tennessee.

Todd, Keith (Ed.), 1970. The Water Encyclopedia. Water Information Center. Port Washington, New York.

Upper Colorado Region State-Federal Inter-Agency Group, 1971. "Upper Colorado Region Comprehensive Framework Study." Denver, Colorado.

Upper Mississippi River Basin Coordinating Committee, 1972. "Upper Mississippi River Comprehensive Basin Study." Sioux City, Iowa.

U.S. Army Corps of Engineers, 1970. "EIS, Delaware River Basin Tocks Island Lake." Pittsburgh, Pennsylvania.

U.S. Army Corps of Engineers, March 1978. "Draft EIS, Missouri River." Sioux City, Iowa.

U.S. Army Corps of Engineers, July 1979. "Preliminary Inventory of Hydropower Resources." National Hydroelectric Power Resources Study.Institute for Water Resources, Fort Belvoir, Vifginia.

U.S. Army Corps of Engineers, August 1980a. "Draft Regional Report: Volume XVI." (S.E.R.C. & Puerto Rico) of the National Hydroelectric Power Resources Study. Atlanta, Georgia.

U.S. Army Corps of Engineers, Sepetember 1980b. "Draft, MAIN Reliability Council, National Hydroelectric Power Resources Study." Chicago, Illinois.

U.S. Army Corps of Engineers, New England Division, August 1980c. National Hydroelectric Power Resources Study: Northeast Power Coordinating Council Regional Report, Volume XV, 95 (review draft). Waltham, Massachusetts.

U.S. Atomic Energy Commission, 1974. "Environmental Survey of the Uranium Fuel Cycle." Report No. WASH-1248. National Technical Information Service, Springfield, Virginia

U.S. Atomic Energy Commission, 1979. "Comparative Risk-Cost Benefit Study of Alternative Sources of Electrical Energy." Report No. WASH-1224. U.S. Government Printing Office, Washington, D.C.

U.S. Bureau of Land Management, 1979. "Final EIS, Federal Coal Management Program." U.S. Government Printing Office, Washington, D.C.

U.S. Department of Agriculture, Forest Service, January 1979. Map--"National Wilderness Preservation System and Recommended Allocations of RARE II Areas." U.S. Government Printing Office, Washington, D.C.

U. S. Department of Commerce, National Marine Fisheries Service, December 1974. Lynn Canal Resource Assessment, (Eds.) Theodore Meyers, Reed E. Harris. Seattle, Washington.

U.S. Department of Commerce, 1977. "Energy Supply and Conventional Impacts--Conventional Energy Sources." Northwest Energy Policy Project. Portland, Oregon. National Technical Information Service. Report No. TB276410. Springfield, Virginia.

U.S. Department of Energy, June 1979a. Small Hydropower Development Program. DOE/EA-0040. Washington, D.C.

U.S. Department of Energy, September 1979b. "Regional Issue Identificaiton and Assessment." Office of the Assistant Secretary for Environment, Office of Technology Impacts Regional Assessments Division. Washington, D.C.

U.S. Department of Energy, April 1980. "Revised Draft, Environmental Impact Statement; the Role of the Bonneville Power Administration in the Pacific Northwest Power Supply System, Including its participation in a hydrothermal power program." DOE/EIS-0066. U.S. Government Printing Office, Washington, D.C.

U.S. Department of Energy, January 1979a. "A Review of State/Federal Environmental Regulations Pertaining to the Electrical Effects of Overhead Transmission Lines: 1978." National Tehcnical Information Service. Report No. HCP/EV-1802. Springfield, Viriginia.

U.S. Department of Energy, June 1979b. "Small Hydropower Development Program." Report No. DOE/EA-0040. U.S. Government Printing Office, Washington, D.C.

U.S. Department of Energy, September 1979c. "Regional Issue Identification and Assessment, First Annual Report." U.S. Government Printing Office, Washington, D.C.

U.S. Department of Energy, June 1980. Technology Characterizations. Report No. DOE/EV-0072. Washington, D.C.

U.S. Department of the Interior, Geological Survey, 1970. The National Atlas of the United States of America. Washington, D.C.

U.S. Department of the Interior, Heritage Conservation and Recreation Service, 1979. Map -- "National Wild and Scenic Riverts System." Washington, D.C.

U.S. Fish and Wildlife Service, December 1976a. "Assessment of Effects of Altered Stream Flow Characteristics on Fish and Wildlife, Part A: Rocky Mountain and Pacific Northwest Executive Summary." FWS/OBS076/78. Fort Collins, Colorado.

U.S. Fish and Wildlife Service, December 1976b. "The Effects of Altered Streamflows on Fish and Wildlife in California." FWS/OBS-76/33. Fort Collins, Colorado.

U.S. Fish and Wildlife Service, 1977. "Impact of Water Level Changes on Woody Riparian and Wetland Communities, Volume II Southern Forest Region." Atlanta, Georgia.

U.S. Fish and Wildlife Service, 1977-78. "Amphibians and Reptiles, The Declining Species" U.S. Government Printing Office, Washington, D.C.

U.S. Fish and Wildlife Service, October 1978a. "Western Reservoir and Stream Habitat Improvements Handbook." FWS/OBS-78/56. Fort Collins, Colorado

U.S. Fish and Wildlife Service, December 1978b. "Instream Flow Methodologies in Regional and National Assessments." Instream Flow Information Paper No. 7, FWS/OBS-78/61. Fort Collins, Colorado

U.S. Fish and Wildlife Service, 1979. "Classification of Wetlands and Deepwater Habitats in the U.S." U.S. Government Printing Office, Washington, D.C.

U.S. Fish and Wildlife Service, 1980. "Endangered and Threatened Species in the Southeast United States - Region IV." Atlanta, Georgia.

U.S. Water and Power Resources Service, July 1980. "Report on Assessment of Small Hydroelectric Development at Existing Facilities." Denver, Colorado.

U.S. Water Resources Council, April 1978a. "The Nation's Water Resources 1975-2000, Volume A-1, Economic, Social, and Environmental Data." Second National Water Assessment. Statistical Appendix, U.S. Government Printing Office, Washington, D.C.

U.S. Water Resources Council, December 1978b. "The Nation's Water Resources 1975-2000, Volume 1: Summary." Second National Water Assessment. U.S. Government Printing Office, Washington, D.C.

University of Oklahoma, Science and Public Policy Program, May 1975. "Energy Alternatives: A Comparative Analysis." Norman, Oklahoma.

Ward, James V. and Jack A. Stanford, Editors, 1979. The Ecology of Regulated Streams. Plenum Press, New York, New York.

Zoellner, David R., 1979. "Hydroelectric Power Generation: Water Resource Impacts of Large-Scale and Small-Scale Development." Institute for Water Resources, Fort Belvoir, Virginia.

Electrical World, September 15, 1980. "Annual Electrical Industry Forecast." McGraw-Hill, Inc., New York, New York.

Graf, William, Febraury 1980. "The Effect of Dam Closure on Downstream Rapids." Water Resources Research. Volume 16, Number 1., pp. 129-136.

Harza Engineering Company, Inc., March 1980. "The Magnitude and Regional Distribution of Needs for Hydropower," Report for the National Hydropower Study. Institute for Water Resources, Fort Belvoir, Virginia.

INTASA, Inc., December 1980. "Categorical Exemption from Licensing Under Part 1 of the Federal Power Act for Small Hydroelectric Power Projects with an Installed Capacity of 5 Megawatts or Less." Menlo Park, California. Report to FERC, No. FERC/EA-0002RM.

New York State Energy Research and Development Authority and Gibbs and Hill, Inc., March 1980. "Small Hydroelectric Project Manual." Prepared for the Appalachian Regional Commission. Washington, D.C.

Pacific Gas and Electric Company, October 1978. "The Geysers." San Francisco, California.

Pacific Northwest River Basins Commission, Power Planning Committee, July 1980. "Review of Power Planning in the Pacific Northwest Calendar Year 1969." Portland, Oregon.

Oliver, Wendell H., 1975. "Wildlife Problems Associated with Reservoirs for Electrical Power Generation." Paper presented at Western Association of State Game and Fish Commissioners. 54th Annual Conference. Albuquerque, New Mexico.

Ruedisili, Lon C. and Morris W. Firebaugh, 1978. Perspectives on Energy - Issues, Ideas and Environmental Dilemmas. Oxford University Press. New York, New York.

SRI International, General Research Corporation and Armstrong Associates, June 1980. "Draft Environmental Impact Statement, Small Power Production and Cogeneration Facilities--Qualifying Status/Rates and Exemptions." Menlo Park, California. Prepared for the Federal Energy Regulatory Commission.

Tudor Engineering Company, December 1978. "Lake Mendocino Power Project." Report for the City of Ukiah. Ukiah, California.

Ukiah, City of, May 1980. "Application for Preliminary Permit for Warm Springs Power Plant, Sonoma County, California." Ukiah, California.

Brown, Peter W. and Anthony W. Buston, January 30, 1979. "Federal Legal Obstacles and Incentives to the Development of the Small-Scale Hydro-electric Potential of the Nineteen Northeastern United States." Energy Law Institute. Franklin Pierce Law Center. Concord, New Hampshire. Prepared for U.S. Department of Energy.

Brown, Peter W. and William H. Wilson, November 9, 1979. "Executive Summary of the Legal and Institutional Obstacles and Incentives to the Development of Hydroelectric Power: A Synthesis of five Case Studies." Energy Law Institute. Franklin Pierce Law Center. Concord, New Hampshire. Prepared for National Conference of State Legislatures.

Edison Electric Institute, 1974. "Historical Statistics of the Electric Utility Industry Through 1970." New York, New York.

Edison Electric Institute, November 1979. Statistical Year Book of the Electric Utility Industry. Washington, D.C.

Energy Users Report, April 3, 1980. "Northwest Utilities, Dam Owners Instructed on Small Hydro Funding." Current Reports. Washington, D.C.

Federal Energy Regulatory Commission, 1979. "Hydropower Licenses and Preliminary Permits." Office of Electric Power Regulation. Washington, D.C.

Gladwell, John S. and Calvin C. Warnick, September 1978. "Low-Head Hydro--An Examiniation of An Alternative Energy Source." Idaho Water Resources Research Institute. Moscow, Idaho.

Institute for Water Resources, March 1979. Hydropower: A National Energy Resource. Fort Belvoir, Virginia.

Marker, Gordon A., March 1979. "Socio-Economic Development: A Private Development View." Hydropower: A National Energy Resource. Institute for Water Resources, Fort Belvoir, Virginia.

National Water Commission, 1973. Water Policies for the Future. Final Report to the President and to the Congress of the United States by the National Water Commission. U.S. Government Printing Office. Washington, D.C.

New York State Energy Research and Development Authority and Gibbs and Hill, Inc., March 1980. "Small Hydroelectric Project Manual." prepared for the Appalachian Regional Commission. Washington, D.C.

Price, Truman, February 1971. "Hydroelectric Power Policy." Report to the National Water Commission. Washington, D.C.

U.S. Army Corps of Engineers, July 1979. "Feasibility Studies for Small-Scale Hydropower Additions: A Guide Manual." Fort Belvoir, Virginia.

U.S. Army Corps of Engineers, October 1980. National Hydropower Study. Project data and computer records. Hydrologic Engineering Center. Davis, California.

U.S. Department of Energy, 1978. Annual Report to Congress - 1978. U.S. Government Printing Office, Washington, D.C.

U.S. Department of Energy, 1979. "Annual Report to Congress, Volume Three: Projections." U.S. Government Printing Office, Washington, D.C.

U.S. Department of Energy, April 1980. "Inventory of Power Plants in the United States." U.S. Government Printing Office, Washington, D.C.

Armacost, Victor, L., July 19 "Lower Snake River Fish and Wildlife Compensation." in The Mitigation Symposium. Report RM-65. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Bonneville Power Administration, 1981. "Pacific Northwest Electric Power Planning and Conservation Act--A Summary." Portland, Oregon.

Brown, Peter W. and Anthony W. Buxton, January 30, 1979. "Federal Legal Obstacles and Incentives to the Development of the Small-Scale Hydroelectric Potential of the Nineteen Northeastern United States." Energy Law Institute. Franklin Pierce Law Center. Concord, New Hampshire. Prepared for U.S. Department of Energy.

Commission on Federal Paperwork, February 25, 1977. Environmental Impacts Statements. Washington, D.C.

Davis, Robert K., Steven H. Hanke, Gerald C. Horak, Kathleen A. Carroll, and Robert J. Barbera, 1973. "An ex post evaluation of fish and wildlife mitigation." Bureau of Sport Fisheries and Wildlife, Washington, D.C. Cited in Horak, 1979.

Dziedzic, Eugene S. and Wendell Oliver, July 1979. "Mitigation--We Won't Settle For Less." in The Mitigation Symposium. Report RM-65. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Ebel, Wesley, 1979. "Effects of Hydropower Projects on Fish Populations." in Hydropower: A National Energy Resource. Proceedings of a conference sponsored by the Engineering Foundation in cooperation with the U.S. Army Corps of Engineers. March 11-16, 1979. Fort Belvoir, Viriginia.

Energy Users Report, July 3, 1980. "House Kills White House Plan for Energy Mobilization Board." in Current Reports, Washington, D.C.

Environment Reporter, September 19, 1980. "Variety of Businesses Oppose Superfund While Administration Urges Quick Action." in Current Reports, Washington, D.C.

Federal Power Commission, November 1976. "Significant Interrelationships Between Electric Power Generation and Natural and Developed resources in the Connecticut River Basin." Office of Energy Systems. U.S. Government Printing Office, Washington, D.C.

Feine, Paul M., December 22, 1980. Feine Commmunications. Washington, D.C. Personal Communication.

Gard, Stephen W., July 1979. "Unmet Mitigation in the Lower Mississippi River and Tributaries." in The Mitigation Symposium. Report RM-65. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Gladwell, John S. and Calvin C. Warnick, September 1978. "Low-Head Hydro--An Examination of An Alternative Energy Source." Idaho Water Resources Research Institute. Moscow, Idaho.

Horak, Gerald C., July 1979. "The Status and Success of fish and Wildlife Mitigation in Western Resource Projects 1946-1979." in The Mitigation Symposium. Report RM-65. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Horak, Gerald C., 1974. "An ex post evaluation of fish and wildlife mitigation." MS thesis. Johns Hopkins University, Baltimore, Maryland. Cited in Horak, 1979.

Horak, Gerald C., 1973. "A preliminary evaluation of fish and wildlife mitigation in federal projects." Nat. and Soc., New York, New York. Cited in Horak, 1979.

Inside EPA, June 27, 1980. "Costle Attacks Industry CAA Revisions, Warns Act May be Gutted." Inside Washington Publishers. Washington, D.C.

Institute for Water Resources, March 1979. Hydropower: A National Energy Resource. Fort Belvoir, Virginia.

Jahn, Laurence R., July 1979. "Summary of the Symposium, and Recommendations for Improving Mitigation in the Future." in The Mitigation Symposium. Report RM-65. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Knapp, Bill, September 1980. U.S. Fish and Wildlife Service. Newton Corner, Massachusetts. Personal Communication.

Knight, Foster, September 1980. Office of General Counsel. Council on Environmental Quality, Washington, D.C. Personal Communication.

Mih, Walter C. and Gary C. Bailey, July 1979. "A Machine for Mitigation of Salmonid Spawning Habitat from Silting." in The Mitigation Symposium. Report RM-65. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Natural Resources Law Institute, March 1980. "Fish and Wildlife Coordination Act and Columbia Basin Water Project Operations." Anadromous Fish Law Memo. Number 6. Lewis and Clark Law School, Portland, Oregon.

Nelson, R. Wayne, Gerald C. Horak, Martin H. Lewis, and Joanne S. Colt, 1966. "Assessment of Effects of Altered Streamflow Characteristics on Fish and Wildlife." FWS/OBS-76/29. Western Energy and Land Use Team, Fort Collins, Colorado. Cited in Horak, 1979.

Nelson, R. Wayne, Gerald C. Horak, James E. Olson, October 1978a. "Western Reservoir and Stream Habitat Improvements Handbook." Enviro Control, Inc. Prepared for the Western Energy and Land Use Team. Office of Biological Services. Fish and Wildlife Service. FWS/OBS-78/56.

Nelson, R. Wayne, Gerald C. Horak, Martin H. Lewis, Joseph M. Solomon, and Shirley Wilsey, 1978b. "Instream Flow Strategies for (13 states)." Separate reports are published for Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, North Dakota, Utah, Washington, and Wyoming. FWS/OBS-89-(35-47). Western Energy and Land Use Team, Fort Collins, Colorado.

New England River Basins Commission, October 1979. "Predicting Impacts in the Connecticut River System - Executive Summary." Boston, Massachusetts.

Oliver, Wendell H., 1975. "Willife Problems Associated with Reservoirs for Electrical Power Generation." Paper presented at Western Association of State Game and Fish Commissioners. 54th Annual Conference. Albuquerque, New Mexico.

Oregon Department of Fish and Wildlife and Washington Department of Fisheries, June 1976. "Columbia River Fish Runs and Fisheries 1957-1975." Volume 2, Number 1. Clackamas, Oregon.

Pacific Northwest River Basins Commission. November 1971. "Columbia-North Pacific Region Comprehensive Framework Study, Appendix XIV, Fish and Wildlife." Vancouver, Washington.

Phelan, Wanda, October 1980. Public Information Officer, U.S. Water Resources Council, Washington, D.C. Personal Communication.

Prosser, Norville S., Robert G. Martin, and Richard H. Stroud, July 1979. "Adequacy and Accuracy of Fish and Wildlife Impact Assessments at Corps of Engineers Projects." in The Mitigation Symposium. Report RM-65. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Rappoport, Ann G., July 1979. "An Evaluation of Alternatives for Improving the Mitigation Process." in The Mitigation Symposium. Report RM-65. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Raymond H.L., 1979. "Effects of Dams and Imppoundments on Migration of Juvenile Chinook Salmon and Steelhead Trout from the Snake River, 1966 to 1975." National Oceanic and Atmospheric Administration. National Marine Fisheries Service, Northwest Fisheries Center, Seattle, Washington. Cited in Ebel, 1979.

Schulthess, Steve, April 1, 1980. "Memorandum Concerning the Fish and Wildlife Coordination Act." Energy Law Institute. Franklin Pierce Law Center, Concord, New Hampshire.

Schweiko, Alex, September 1980. Chief of Planning, Office of the Chief of Engineers. U.S. Army Corps of Engineers. Washington, D.C. Personal communication.

Short, Cathy and mel Schamberger, July 1979. "Evaluation of Impacts on Fish and Wildlife Habitat and Development of Mitigation Measures." in The Mitigation Symposium. Report RM-65. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Shuster, Carl N., 1978. "A Commentary on a Methodology for Assessment of the Environmental Impact of the Electrical Power System Within the Connecticut River Basin." in Energy Technology V: Challenges to Technology. Government Institutes Inc. U.S. Government Printing Office, Washington, D.C.

Stalnaker, C.B. and Arnette, J.L., 1976. "Methodologies for the Determination of Stream Resource Flow Requirements: An Assessment." Prepared for U.S. Fish and Wildlife Service. Office of Biological Services. Western Water Allocation. Utah State University. Logan, Utah.

Tennant, Donald Leroy, 1976. "Instream Flow Regimes for Fish, Wildlife, Recreation and Related Enviornmental Resources." Fisheries. Volume 1, Number 4.

U.S. Department of Energy, April 1980. "Revised Draft Environmental Impact Statement - the Role of the Bonneville Power Administration in the Pacific Northwest Power Supply System." U.S. Government Printing Office, Washington, D.C.

U.S. Department of the Interior, March 1976. "Bumping Lake Enlargement." Joint Feasibility Report. Bureau of Reclamation and Fish and Wildlife Service. Boise, Idaho.

U.S. Fish and Wildlife Service, October 1979. "Initiatives Related to Small-Scale Hydropower Expansion in the Northeastern United States." Region 5, Newton Corner, Massachusetts.

U.S. General Accounting Office, January 11, 1980. "Hydropower--an Energy Source Whose Time Has Come Again." U.S. Government Printing Office, Washington, D.C.

Voigt, Judy A. and Julius G. Nagy, July 1979. "Wildlife Mitigations at Bureau of Reclamation Projects: A Case Study Approach." in The Mitigation Symposium. Report RM-65. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Wood, Roy K. and Bryan L. Swift, July 1979. "Wildlife Conservation Strategy Derived from Case Histories of Ten Federal Water-Resource Projects in the Southeast." in The Mitigation Symposium. Report RM-65. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Johns Hopkins University, 1979. "Problem of Hydroelectric Development at Existing Dams." prepared for U.S. Department of Energy. Baltimore, Maryland.

Sverdrup & Parcel and Associates, Inc. Project Records. San Francisco, California.

U.S. Army Corps of Engineers, North Pacific Division, 1979. "Hydropower Cost Estimating Manual." Prepared for the National Hydropower Study. Institute for Water Resources, Fort Belvoir, Virginia.

U.S. Department of Energy, 1978. "Hydroelectric Plant Construction Cost and Annual Production Expenses 1977." U.S. Government Printing Office, Washington, D.C.

Brown, Peter W., and Anthony W. Buxton, September 11, 1978. "Preliminary Analysis of Legal Obstacles and Incentives to the Development of Low-Head Hydroelectriic Power in the Northeastern United States." Energy Law Institute. Franklin Pierce Law Center, Concord, New Hampshire. Prepared for U.S. Department of Energy.

Brown, Peter W., and Anthony W. Buxton, January 30, 1979a. "Federal Legal Obstacles and Incentives to the Development of the Small-Scale Hydroelectric Potential of the Nineteen Northeastern United States." Energy Law Institute. Franklin Pierce Law Center, Concord, New Hampshire. Prepared for U.S. Department of Energy.

Brown, Peter W., and Anthony W. Buxton, May 1, 1979b. "Executive Summary - Legal Obstacles and Incentives to Small-Scale Hydroelectric Development in the Six Middle Atlantic States." Energy Law Institute. Franklin Pierce Law Center, Concord, New Hampshire. Prepared for U.S. Department of Energy.

Brown, Peter W., and Martin Ringo, January 30, 1979. "Fundamental Economic Issues in the Development of Small-Scale Hydro." Energy Law Institute. Franklin Pierce Law Center, Concord, New Hampshire. Prepared for U.S. Department of Energy.

Brown, Peter W., and William H. Wilson, November 9, 1979. "Executive Summary of the Legal and Institutional Obstacles and Incentives to the Development of Hydroelectric Power: A Snythesis of Five Case Studies." Energy Law Institute. Franklin Pierce Law Center, Concord, New Hampshire. Prepared for National Conference of State Legislatures.

Cronmiller, Thomas, Arlene Lavrenitis, Donnie Pope, and Frederick Schmidt, August 31, 1979. "Executive Summary of the Legal and Institutional Obstacles and Incentives to the Development of Small-Scale Hydroelectric Potential in the Seven Mid-Western States." Energy Law Institute. Franklin Pierce Law Center, Concord, New Hampshire. Prepared for U.S. Department of Energy.

Federal Energy Regulatory Commission, 1979. "Hydropower Licenses and Preliminary Permits." Office of Electric Power Regulation. Washington, D.C.

Federal Power Commission, May 4, 1974. "Environment and Conservation Packet, Excerpts, Rules of Practice and Procedure and Regulations Under the Federal Power Act." Washington, D.C.

Gladwell, John S. and Calvin C. Warnick, September 1978. "Low-Head Hydro--An Examination of an Alternative Energy Source." Idaho Water Resources Research Institute, Moscow, Idaho.

Gore, Greg, January 24, 19801. "Memorandum Concerning the National Scenic Trails Act." Energy Law Institute. Franklin Pierce Law Center, Concord, New Hampshire.

Gore, Greg, January 25, 1980b. "Memorandum Concerning the National Wilderness Preservation System." Energy Law Institute. Franklin Pierce Law Center, Concord, New Hampshire.

Gore, Greg, January 29, 1980c. "Memorandum Concerning The Wild, Scenic, and Recreational Rivers Act." Energy Law Institute. Franklin Pierce Law Center, Concord, New Hampshire.

Institute for Water Resources, 1979. Hydropower: A National Energy Resource. Proceedings of a Conference sponsored by the Engineering Foundation in cooperation with the U.S. Army Corps of Engineers. March 11-16, 1979. Fort Belvoir, Virginia.

Natural Resources Law Institue, March 1980. "The Fish and Wildlife Coordination Act and Columbia Basin Water Project Operations." Anadromous Fish Law Memo. Number 6. Lewis and Clark Law School, Portland, Oregon.

Oliver, Wendell H., 1975. "Wildlife Problems Associated with Reservoirs for Electrical Power Generation." Paper presented at Western Association of State Game and Fish Commissioners. 54th Annual Conference, Albuquerque, New Mexico.

Radzik, Edward and Deborah Reynolds, August 15, 1979. "Legal Obstacles and Incentives to the Development of Small-Scale Hydroelectric Power in New York." Energy Law Institute. Franklin Pierce Law Center, Concord, New Hampshire. Prepared for U.S. Department of Energy.

Reynolds, Debbie, January 27, 1980a. "Memorandum Concerning the Environmental Protection Agency." Energy Law Institute. Franklin Pierce Law Center, Concord, New Hampshire.

Reynolds, Debbie, January 28, 1980b. "Memorandum Concerning the Endangered Species Act of 1973." Energy Law Institute. Franklin Pierce Law Center, Concord, New Hampshire.

Schulthess, Steve, April 1, 1980. "Memorandum Concerning the Fish and Wildlife Coordination Act." Energy Law Institute. Franklin Pierce Law Center, Concord, New Hampshire.

U.S. Army Corps of Engineers, September 28, 1979. "Digest of Water Resources Policies and Authorities." Office of the Chief of Engineers. Washington, D.C.

U.S. Environmental Protection Agency, May 30, 1980. "New RCRA Regulations." Material distributed at public meeting, San Francisco, California.

U.S. Fish and Wildlife Service, Office of Biological Services, October 1977. "Promising Strategies for Reserving Instream Flows." Report No. FWS/OBS-77/29. Western Energy and Land Use Team. Fort Collins, Colorado.

U.S. Senate, June 19, 1980. "Energy Security Act." Conference Report No. 96-824. 96th Congress. Second Session. U.S. Government Printing Office, Washington, D.C.

American Fiisheries Society, 1979. "Effects of Dams and Impoundments on Mitigation of Juvenile Chinook Salmon and Steelhead from the Snake River, 1966-1975."

Arvanitidis, N.V., and J. Rosing, February 1970. "Composite Representation of a Multi-Reservoir Hydroelectric Power System." IEEE Transactions on Power Apparatus and Systems. Volume PAS-89, Number 2.

Bonneville Power Administration, 1976. "Environmental Impacts of the Generation of Electricity in the Pacific Northwest: Volumes I and II." Portland, Oregon.

Bonneville Power Administration, 1980. "Revised Draft Enviornmental Impact Statement - The Role of the Bonneville Power Administration in the Pacific Northwest Power Supply System." Portland, Oregon.

Callaway, D.C., J.E. Levy, and E.B. Henderson, 1976. "The Effects of Power Production and Strip-Mining on Local Navajo Populations." Lake Powell Research Bulletin Number 22. University of California. Los Angeles, California.

Comptroller General, 1979. "Colorado River Basin Water Problems: How to Reduce Their Impact." Report to the Congress of the United States. U.S. Government Printing Office, Washington, D.C.

Dunstan, Lyle A., 1979. "Coordinated Operation of Mid-Columbia River Hydro Projects." in Hydropower: A National Energy Resource-Proceedings. Sponsored by the Engineering Foundation, in cooperation with the U.S. Army Corps of Engineers. Institute for Water Resources, Fort Belvoir, Virginia.

Federal Power Commission, 1976. "Significant Interrelationships Between Electric Power Generation and Natural and Developed Resources in the Connecticut River Basin." Office of Energy Systems. Washington, D.C.

Institute for Water Resources and Hydroelectric Engineering Center,, 1979. "Preliminary Inventory of Hydropower Resources." 6 Volumes. Fort Belvoir, Virginia.

Ives, B. and W.D. Schulze, 1976. "Boomtown Impacts of Energy Development in the Lake Powell Region." Lake Powell Research Bulletin Number 28. University of California, Los Angeles, California.

Kunitz, S.J., 1976. "The Relationship of Economic Variations to Mortality and Fertility Patterns on the Navajo Reservation." Lake Powell Research Bulletin Number 20. University of California, Los Angeles, California.

Little, R.L., 1977. "Some Special Consequences of Boomtowns." Lake Powell Research Bulletin Number 57. University of California, Los Angeles, California.

Lovejoy, S., 1977. "Local Perceptions of Energy Development: The Case of the Kaiparowits Plateau." Lake Powell Research Bulletin Number 62. University of California, Los Angeles, California.

New England River Basins Commission, 1979. "Cumulative Impacts Prediction Potential: An Assessment of Existing Modelling Tehcnology and Data Resources." Boston, Massachusetts.

Pacific Northwest Laboratory, 1978. "Spawning and Movements of Smallmouth Bass in the Mid-Columbia River." Seattle, Washington.

Pogue, Thomas F. and L.G. Sgontz, 1978. Government and Economic Choice - An Introduction to Public Finance. Houghton Mifflin Company, Boston, Massachusetts.

Robbins, L.A., 1975. "The Impact of Power Developments on the Navajo Nation," Lake Powell Research Bulletin Number 7. University of California, Los Angeles, California.

Schulze, W., S. Ben-David, D. Brookshire, and R. Whitworth, 1975. "The Macroeconomic Impact of Energy Development in the Lake Powell Area." Lake Powell Research Bulletin Number 11. University of California, Los Angeles, California.

Schuster, Carl N. Jr., 1978. "A Commentary on a Methodology for Assessment of the Environmental Impact of the Electric Power System Within the Connecticut Riiver Basin." Reprinted from Energy Technology V: Challenges to Technology. Government Institutes, Inc., Washington, D.C.

Seinwill, Gerald D. and Frank S. Davenport, 1979. "Federal Policy Influence on Allocation of Water for Power--Thermal and Hydro." Presented to the Specialty Conference on Conservation and Utilization of Water and Energy Resources. American Society of Civil Engineers. San Francisco, California.

U.S. Department of the Interior, 1976. "Bumping Lake Enlargement, Yakima Project - Joint Feasibility Report." Boise, Idaho.

U.S. Fish and Wildlife Service, Region 5, 1979. "Initiatives Related to Small Scale Hydropower Expansion in the Northeastern United States." Newton Corner, Massachusetts.

U.S. Water Resources Council, 1978. "The Nation's Water Resources - The Second National Water Assessment by the U.S. Water Resources Council." Statistical Appendix Volume A-3. Water Supply and Use Analysis. U.S. Government Printing Office, Washington, D.C.

Washington Department of Game, 1976. "The Impact of the Grand Coulee Third Powerhouse Extension on Fish and Wildlife Populations." Columbia River, Washington.

Washington Department of Game, 1977. "An Assessment of Chief Joseph Dam Unit to 27 Project Impacts and Their Mitigation and Compensation by Means of the Habitat Unit Evaluation Procedure."

Washington Department of Game, August 1979. "Mid-Columbia Concerns." <u>Applied Research</u>.

APPENDIX A

DEFINITIONS FOR CONSTRUCTION

AND OPERATION ACTIONS

Each type of hydropower development depicted by the classification system involves a series of actions in construction and operation that change conditions in the environment, causing a series of environmental impacts. The important types of actions typically associated with hydropower projects appear in Table A-1. Brief definitions of these actions, as well as definitions of other terms in the classification system, are given below. Figure A.1 illustrates the relative schedule of the actions as a percentage of construction and operating time. This helps distinguish long-term actions from short-term ones and therefore gives a partial indication of the significance of each action.

Not all types of hydropower development require all of these actions, and thus all types of hydropower development do not have the same environmental consequences. The necessary actions for a given project will depend partly on specific site characteristics, but they are largely a function of the type of project. For example, stream diversion and several other construction activities are not required for a hydropower retrofit project at an existing dam. Generalizations of typical actions and other system components and resources involved in the development of each of the categories of projects defined by the classification system appear in a series of hydropower plant configurations in Appendix C. Each configuration depicts a fictional installation based on typical hydroelectric plant characteristics for the classification considered. An actual hydroelectric installation depends greatly on site-specific conditions such as stream flow characteristics, area topography, system load curves, and the market needs for the power. Therefore, the numerical data presented on the configuration sheets should be considered as rough, order-of-magnitude approximations only. However, they are useful for estimating the types and magnitudes of impacts of different categories of hydropower development.

Table A-1
CONSTRUCTION AND OPERATION ACTIONS ASSOCIATED WITH HYDROPOWER DEVELOPMENT

CONTRUCTION	OPERATION
1. Exploration	1. Impoundment and Creation of Man-Made Lake
2. Access Roads	2. Turbine Release
3. Site Preparation	a) Reservoir Fluctuation
4. Stream Diversion	b) Downstream Fluctuation
5. Reservoir Clearing	3. Surface Releases
6. Reservoir Dredging	4. Power Generation
7. Excavation	5. Maintenance
8. Spoils Area	
9. Borrow Pits	
10. Dam Construction	
11. Powerhouse Construction	
12. Switchyard Construction	
13. Transmission Lines	
14. Accommodation of Workforce	

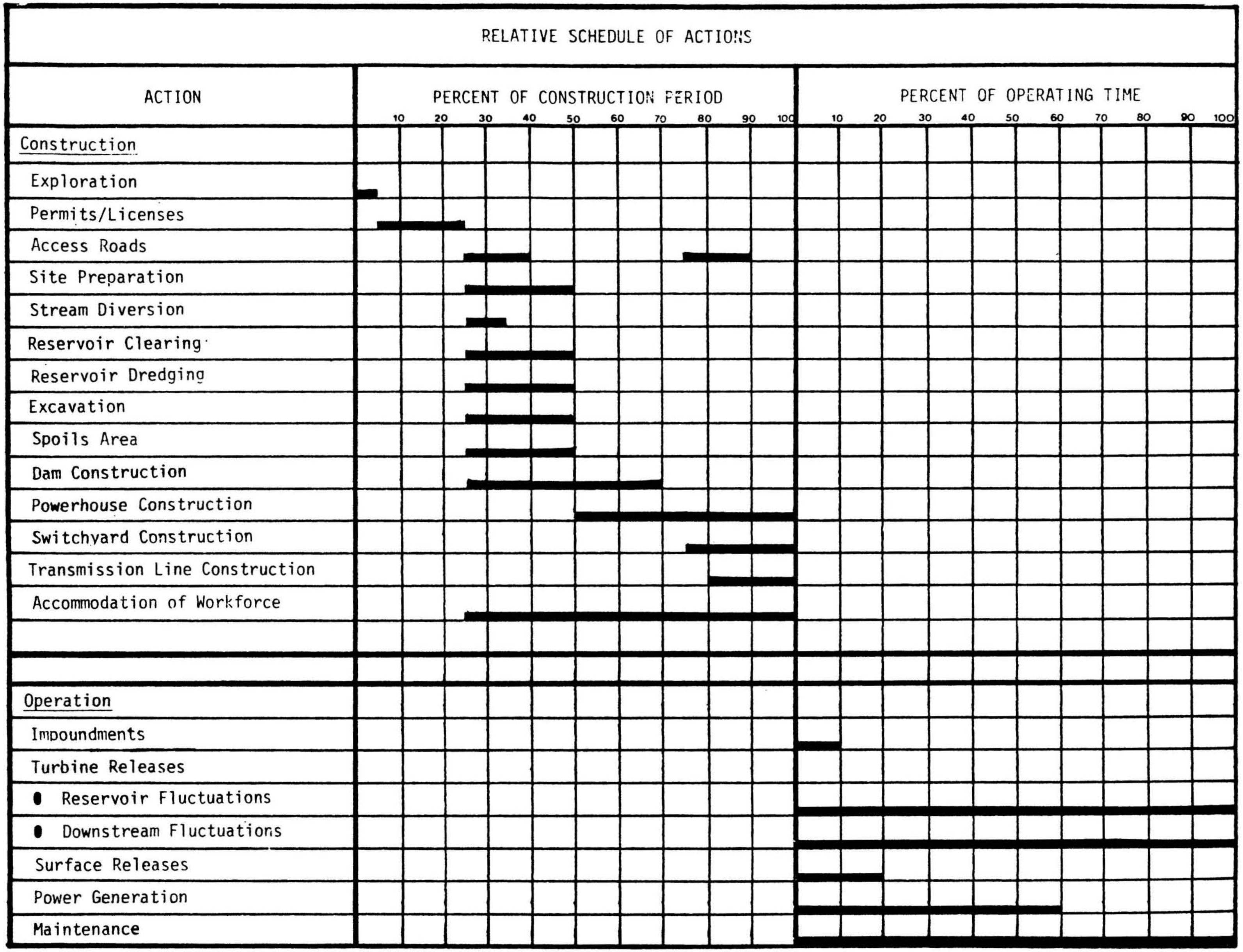


Figure A.1 RELATIVE SCHEDULE OF ACTIONS FOR HYDROPOWER DEVELOPMENT

DEFINITIONS OF TERMS USED IN MATRIX

Operation:

1. Run of River

A conventional hydroelectric facility usually associated with a dam constructed across a river to maintain a minimum or constant water level, usually for navigation, diversion or some other non-power purpose. The power generated is dependent on natural daily, weekly or seasonal flow patterns and upstream regulation. Run-of-river plants are often best suited for base-load power generation as most plants lack sufficient storage for peaking operations.

2. Storage

A hydroelectric facility which utilizes a large pond or reservoir to control flow and power generation. Often the generating capacity of storage plants is very high in relation to streamflow because of the heads achieved with large impoundments. Storage plants can be operated in several ways, but are well-adapted to peak-load operations.

Site Status:

3. Undeveloped

A site on a river or stream which is presently in a natural state. There are no existing dams or powerhouses, but the site has the potential to produce hydroelectric power.

4. Existing Dam

A barrier, currently in place on a stream or river, that is used to regulate flow. The dam may be utilized for several purposes, but is also available for power production.

5. Conduit

A man-made conveyance system used to divert water from a natural stream for one of several possible purposes. This can include irrigation, consumption or the creation of increased hydraulic head.

Construction Actions:

1. Exploration

The process of investigating and gathering data about a site prior to setting up or starting construction. Exploration can include collecting environmental data, examining geological and agricultural maps of the area, taking soil borings and making field inspections.

2. Access Roads

The construction and opening of approach roads to the proposed site. This included clearing of vegetation, grading and possible surfacing.

3. Site Preparation

Preliminary activities associated with the construction of a hydroelectric facility. Activities can include preparing the contractor's work area, general site grading and establishing site utilities.

4. Stream Diversion

The temporary re-routing of a stream or river in order to construct a dam. This is accomplished with cofferdams and conduits.

5. Reservoir Clearing

The process of removing trees and vegetation from the area where water will be ponded. Reservoir clearing may also include grubbing where required by local authorities.

6. Reservoir Dredging

The removal of excess sediment from the bottom of an existing reservoir. Dredging increases or restores the storage capacity of the reservoir.

7. Excavation

The removal and transportation of soil and rock from the dam and power house site. Excavation is required for preparation of foundation and abutment areas.

8. Spoils Area

An area carefully selected to house waste materials from dredging and excavating operations. Because dredged materials sometimes hold high concentrations of heavy metals, pesticides and other toxic materials, their disposal is a matter of extreme concern.

9. Borrow Pits

An area, near the dam site, where earth material is excavated for use in the construction of the dam. Earth and rock-fill dams are usually built from material obtained locally.

10. Dam Construction

The forming of a barrier across a river or stream which creates hydrostatic head and regulates flow. The exact activities are dependent upon the type of dam, but can include excavation, earthwork, concrete production, forming, placing, compacting, and finishing. The process can be lengthy, and requires heavy equipment and large construction crews.

11. Powerhouse Construction

The fabrication or modification of a structure to support and house the turbines, generators and discharge structures. The powerhouse is often built out of reinforced concrete. The process includes concrete production, forming and pouring, rebar placement and finishing. The time required to build a powerhouse is dependent on its size and complexity.

12. Switchyard Construction

The erection of steel frames, poles, cables and electrical lines on a site near by but separate from the powerhouse. A switchyard's function is to meter and relay the power produced by the hydroelectric facility. It is comparable to a substation in a transmission system.

13. Transmission Lines

The wires and cables along which the generated electricity is transmitted.

14. Accommodation of Workforce

Housing and provision of services for all of the people working at or near the project site whose jobs are related to any part or phase of the construction activities. The number of people present and their length of stay is dependent upon the type of project.

Operation Actions:

1. Impoundment and Creation of Man-Made Lake

The natural process of letting runoff water collect behind a dam to form a reservoir. The rate of water collection is a function of the streamflow and the size of the reservoir. Run-of-river operations generally have shallow reservoirs that fill relatively soon. Storage reservoirs may take years to fill. A certain level of impoundment is required before power production can commence.

2. Turbine Release

Water passing downstream after flowing near the bottom of the reservoir and through the turbines. Water released at lower depths is characterized by a cool temperature, low dissolved oxygen content and fair amounts of sediment. Regulated turbine releases that alter natural streamflow cause reservoir fluctuations and downstream fluctuations.

Reservoir Fluctuations--The upward and downward movement of the water level in a reservoir. The surface elevation of the reservoir can change if the rate of flow through the dam varies or if the natural runoff rate changes.

Downstream Fluctuations--The rise and fall of the water level below the dam and powerhouse, due to natural or man-made flow changes.

3. Surface Releases

Water passing beyond the dam and powerhouse, either over spillways or through outlets placed near the top of the dam, primarily for flood control. Water released near the surface is characterized by a warm temperature, an adequate amount of dissolved oxygen and small amounts of nutrients and sediment. Surface releases should be infrequent at storage-type installations with an adequately designed flood control zone.

4. Power Generation

The production of electrical energy from the mechanical process of water passing through turbines, which then in turn rotate generators. Power generation is characterized by noise, high voltage electrical systems and electromagnetic fields.

5. Maintenance

All personnel that at sometime need to be at an operational hydroelectric facility site. These personnel may be involved with checking and, if necessary, repairing the mechanical, structural or electrical components of the facility. Other personnel may be visiting the site for security reasons. If the facility is remotely operated, crews will not be present every day, but will make periodic checks.

APPENDIX B

METHODOLOGY FOR SELECTING

THE CLASSIFICATION SYSTEM

The classification system used in this study was developed by reviewing and examining pertinent literature, drawing up several trial systems, and then testing the validity and usefulness of each system by applying the environmental data collected from the Form 2 inventory of the Corps. Refinements and changes were made based on the knowledge and experience of the consultants involved. The three initial possibilities for a workable classification system are shown again as Figure B.1. Throughout all stages of the study a distinction was made between existing sites and undeveloped sites. The environmental impacts associated with hydropower developments at sites with existing dams and facilities are different from those at undeveloped sites; therefore there was little question that these two designations be incorporated into the classification system. The other possibilities considered as classifying factors included run-of-river and peaking designations in order to identify how a hydropower plant is operated; head and capacity as a means of identifying the size and scale of a hydropower project; and reservoir and diversion as description of how water is controlled in connection with a hydroelectric development.

The three beginning systems were tested with the Form 2 data. Seventy-five dams were selected from each of the four Army Corps districts with complete data (at the time): Walla Walla, Fort Worth, Savannah and Wilmington (Figure B.2). The number and types of impact ratings for the 20 environmental factors contained on Form 2 for each district was aggregated for the three alternative definitions (Figure B.3).

The results of the analysis reveal important differences for types of hydropower development and regional characteristics. Under hydropower configuration definition #1, for Walla Walla, nearly 60 negative impacts were recorded for a peaking plants of greater-than-20-meters head as opposed to a total of 20 negative impacts for greater-than-20-meter head run-of-river plants. The incidence of a greater number of impacts for peaking versus run-of-river is consistent for the Walla Walla, Fort Worth and Wilmington districts. However, the Savannah district shows an anomalous profile, with a high number of impacts for less-than-20-meter head for run-of-river

HYDROPOWER CONFIGURATIONS

DEFINITION #1

	RUN OF RIVER				PEAKING			
	Existing		Undevel.		Existing		Undevel.	
Head (meters)	< 20	> 20	< 20	> 20	< 20	> 20	< 20	> 20

DEFINITION #2

	RES.+RES.W/DIV				DIV.		R OF R	
	Existing		Undevel.		Existing		Undevel.	
Capacity (MW)	< 25	> 25	< 25	> 25	< 25	> 25	< 25	> 25

DEFINITION #3

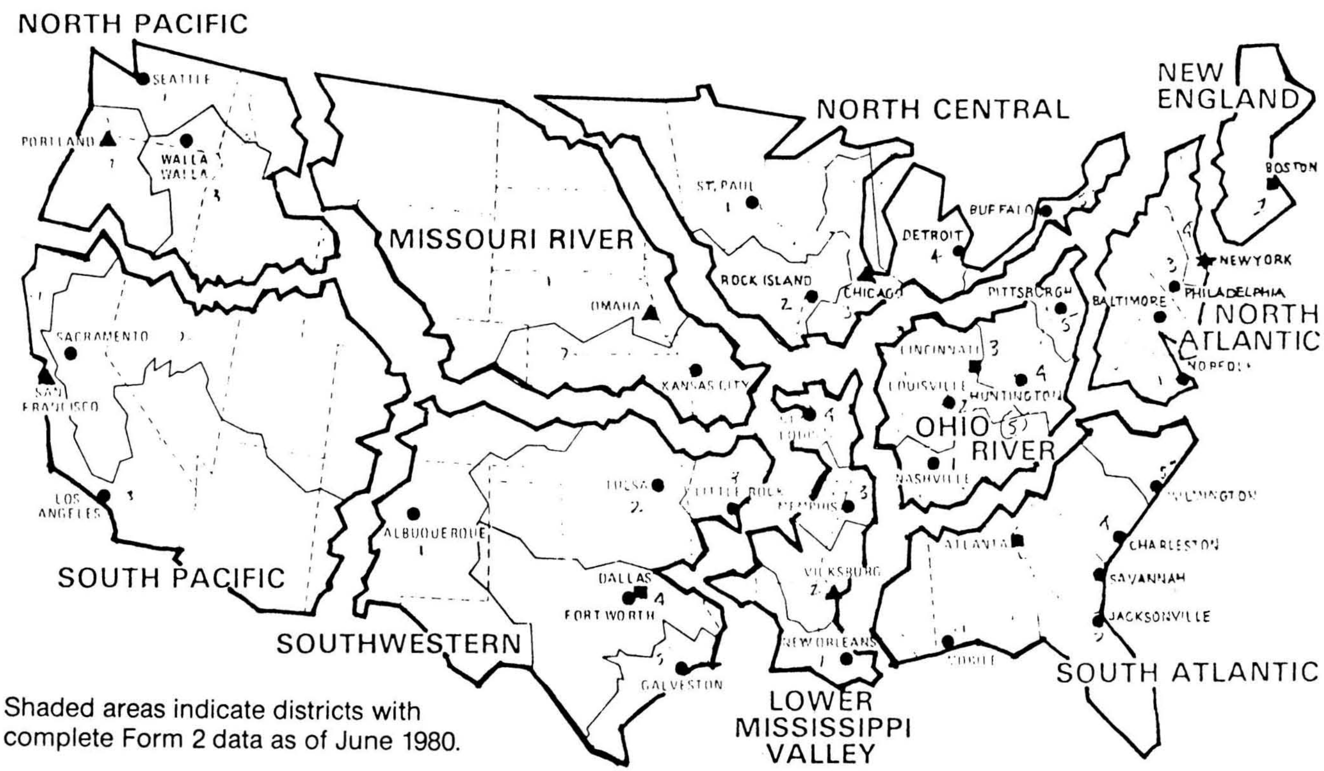
	UNDEVEL.			EXIST. W/POW EXIST.WO/POW		
Capacity (MW)	< 15	15-25	> 25	< 15	15-25	> 25

Notes:

RES = reservoir
DIV = diversion

Undevel = undeveloped site
R of R = run-of-river

Figure B.1 ALTERNATIVE HYDROPOWER CLASSIFICATION SYSTEMS



Note: Shaded areas indicate districts with complete Form 2 data as of June 1980.

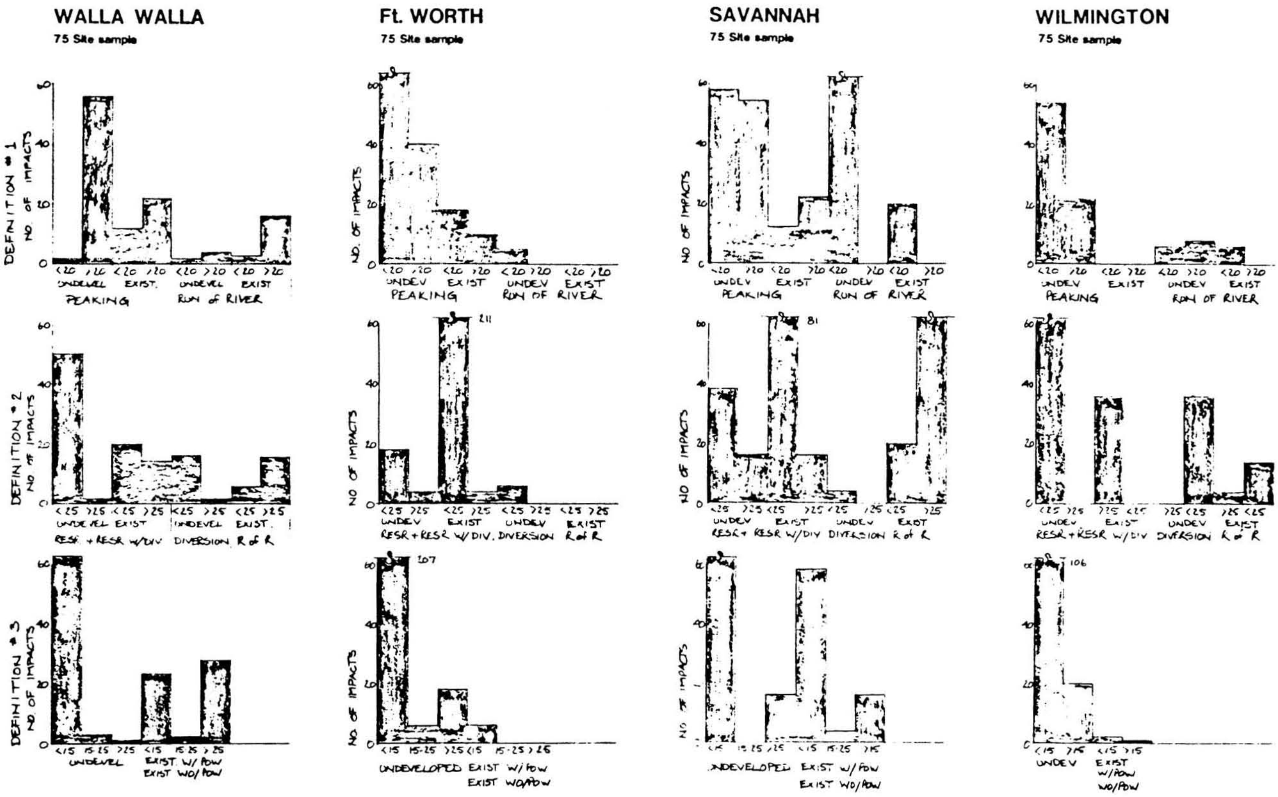
Figure B.2 ARMY CORPS OF ENGINEERS' DIVISIONS AND DISTRICTS undeveloped plants. In general, the profiles for definitions 2 and 3 show that dams associated as reservoir or reservoir with diversion have a larger number of impact ratings than do run-of-river, with the exception, again, of Savannah, capacities of greater than 25 MW correlate with a greater number of impacts than do those of less than 25 MW. Definition #3, "existing dams," with the exception of Savannah, shows that undeveloped sites have a greater number of negative impact ratings than do existing sites with or without power. The consistency of the anomalous ratings for Savannah suggests either (1) unique regional distinctions in terms of impacts, or (2) inconsistency in the rating of environmental impacts among regions.

In addition to displaying the frequency of impacts by various configurations of hydropower, the analysis demonstrates regional variation in the most prevalent impact issues (see Figure B.3). Collectively, the most common environmental impacts among all of the districts are: (1) impacts on fish habitat, either lake or stream, (2) impacts on critical wildlife habitats, (3) impacts on endangered species, (4) impacts on potential wild and scenic rivers, and (5) land-use impacts associated with the displacement of structures, persons, highways and bridges by impoundment.

The comparison of the alternative classification systems reaffirmed that site status--existing or undeveloped--and mode of operation--storage or run-of-river were the most important characteristics of hydropower projects in terms of expected environmental impacts. The site status and operation designations were set as the basis of the classification system.

In addition, the category labeled conduit was incorporated to represent both man-made canals and diversion tunnels. The environmental impacts associated with hydropower developments on a canal or diversion tunnel were considered to be distinct enough to warrant a separate designation.

It was also decided that part of the classification system must pertain to the scale or magnitude of a project. The magnitude of a hydropower project can be indicative of both its engineering design and environmental impact. The scale of a hydropower project can logically be explained either in terms of available head or by the electrical generating capacity. These two



WALLA WALLA	Ft. WORTH	SAVANNAH	WILMINGTON
TOP 10 IMPACT ISSUES by frequency	**TOP 10 IMPACT ISSUES** by frequency	**TOP 10 IMPACT ISSUES** by frequency	**TOP 10 IMPACT ISSUES** by frequency
1 HIGHWAY + RAILROAD MILES	1 POTENTIAL WILD + SCENIC RIVERS	1 FISH HABITAT - STREAM	1 FARM LAND INUNDATED
2 HIGHWAY + RAILROAD BRIDGES	2 HIGHWAY + RAILROAD MILES	2 FISH HABITAT - LAKE	2 HIGHWAY + RAILROAD MILES
3 NATIONAL + STATE PARKS	3 CRITICAL WILDLIFE HABITAT	3 WATER QUALITY	3 HIGHWAY + RAILROAD BRIDGES
4 RECREATIONAL LAKES + RESV.	4 FISH HABITAT - STREAM	4 FARM LAND	4 FISH HABITAT - STREAMS
5 FISH HABITAT - LAKE	5 FISH HABITAT - LAKE	5 CRITICAL WILDLIFE HABITAT	5 PERSONS RELOCATED
6 FISH HABITAT - STREAM	6 ESTUARINE + WETLANDS	6 ENDANGERED SPECIES	6 ESTUARINE + WETLANDS
7 PRIMITIVE OR NATURAL AREA	7 PERSONS RELOCATED	7 POTENTIAL WILD + SCENIC RIVERS	7 CRITICAL WILDLIFE HABITAT
8 CRITICAL WILDLIFE HABITAT	8 TOWNS RELOCATED	8 HIGHWAY + RAILROAD MILES	8 FISH HABITAT - LAKES
9 BUISNESS RELOCATION	9 BUISNESSES RELOCATED	9 PERSONS RELOCATED	9 CULTURAL RESOURCES
10 POTENTIAL WILD/SCENIC RIVER	10 ENDANGERED SPECIES	10 NATIONAL STATE PARKS	10 ENDANGERED SPECIES

Figure B.3 SUMMARY OF IMPACT ISSUES BY ALTERNATIVE HYDROPOWER CLASSIFICATION DEFINITIONS FOR FOUR CORPS DISTRICTS classifications were examined to determine which description would work best in the overall project scheme. Head, the difference in elevation between the upstream side and the downstream side of a dam, relates to both operation and power production. The more head available, the more power that can be generated. In general, hydropower sites with heads of 20 meters (65 feet) or higher are large power producers and are often used as peaking plants. Plants with less than 20 meters of head are somewhat limited in their power production, and are primarily used as base-load operations. The generating capacity of a facility is usually expressed in megawatts (MW), which is a rating of the power available, and is a function of the head and the flow.

After evaluating these choices, we selected generating capacity as the third criterion in defining hydropower. Capacity, expressed in electrical units, was judged to be a more recognized concept, particularly by most lay people. Power-production capacity is also the classification most commonly seen in literature and legislation.

The next step was to group the levels of power production into a set of numerical ranges that were reasonable, as well as effectual in the matrix. Three ranges were selected--less than 5 MW, 5-30 MW, and greater than 30 MW. In reality, the greater than 30-MW range is also considered to be less than 100 MW. This is because the remaining sites capable of generating more than 100 MW are very limited and would require a very site-specific environmental analysis.

The main influences in selecting the ranges were industry and governmental agency standards. Currently, manufacturers have "standard" design equipment for the 10-MW range, and the ranges will increase as the market demand rises. Also, legislation connected with hydropower contains a number of specified limits. Foremost among the legislation are the FERC regulations concerning licensing. The new Energy Security Act of 1980 (Synfuel Act) allows FERC discretionary exemption from licensing for facilities less than 5 MW. Likewise, recent PURPA (Public Utility Regulatory Policies Act) legislation will affect licensing and power sales for some sites up to a size of 30 MW.

Thirty megawatts was considered a good break point for several additional reasons. First, the majority of hydropower sites are less than 30 MW. Second, power plants up to 30 MW are in a fairly feasible financial range. Third, the market for power production in this range exists because the generated electricity can be integrated into the existing load curve in most areas.

The final classification system is shown in Figure 3.4 of the main text.

APPENDIX C

DESCRIPTION OF HYDROPOWER CONFIGURATIONS

NOTE: The following source material was reviewed in developing the descriptions of hydropower configurations: DOE, 1978; Corps, 1979, Sverdrup & Parcel and Associates, Inc., project records; Johns Hopkins University 1979.

RUN-OF-RIVER OPERATION
UNDEVELOPED SITE - LESS THAN 5 MW

SYSTEM:

GENERIC FEATURES

- o Create new dam and reservoir
- o Dam is normally less than 65 feet above stream bed
- o Plant utilizes natural stream flow for power generation
- o Reservoir has little storage capacity so plant operates at essentially constant level
- o Water releases downstream of site are essentially unchanged from normal conditions

CONSTRUCTION ACTIONS

- o Exploration
- o Construction at Access Roads
- o Site Preparation
- o Stream Diversion
- o Reservoir Clearing
- o Excavation
- o Deposition of Spoils Area
- o Creation of Borrow Pits

OPERATION ACTIONS

- o Surface Releases
- o Power Generation
- o Maintenance

COMPONENTS

- o Dam
- o Turbine
- o Generator
- o Transformer
- o Power Plant Structures
- o Transmission Lines
- o Access Roads

RESOURCES USED:

PLANT CHARACTERISTICS

- o 4 MW Plant Capacity
- o 40% Plant Factor
- o 50 Years Service Life
- o 83% Plant Efficiency
- o 40 Feet Head
- o 11.6×10^6 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	0.4 Million

LAND	Acres
o Area Occupied	
Power Plant	10
Reservoir	60

COSTS	Dollars (1980)
o Construction ($2,000/Kw)	$8.0 Million
o Operating and Maintenance	2.7 Million (50 Year Life
o Fishery Mitigation	0.4 Million

PERSONNEL	Workers/Year
o Construction (1.5 Years)	40
o Operation & Maintenance	0.6

RUN-OF-RIVER OPERATION
UNDEVELOPED SITE - 5 MW TO 30 MW

SYSTEM:

GENERIC FEATURES

- Create new dam and reservoir
- Dam is normally less than 65 feet above stream bed
- Plant utilizes natural stream flow for power generation
- Reservoir has little storage capacity so plant operates at essentially constant level
- Water releases downstream of site are essentially unchanged from normal

CONSTRUCTION ACTIONS

- Exploration
- Construction of Access Roads
- Site Preparation
- Stream Diversion
- Reservoir Clearing
- Excavation
- Deposition of Spoils Area
- Creation of Borrow Pits
- Dam Construction
- Switchyard Construction
- Transmission Lines Construction
- Accommodation of Work Force

OPERATION ACTIONS

- Surface Release
- Power Generation
- Maintenance

RESOURCES USED:

PLANT CHARACTERISTICS

- 30 MW Plant Capacity
- 40% Plant Factor
- 50 Years Service Life
- 85% Plant Efficiency
- 40 Feet Head
- 89.4×10^6 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	2.7 Million

LAND	Acres
o Area Occupied	
Power Plant	20
Reservoir	2000

COSTS	Dollars (1980)
o Construction ($2,000/Kw)	$ 60.0 Million
o Operating and Maintenance	$ 7.0 Million (50 Year Life)
o Fishery Mitigation	$ 5.0 Million

PERSONNEL	Workers/Year
o Construction (3 Years)	160
o Operation and Maintenance	1.5

RUN-OF-RIVER OPERATION
UNDEVELOPED SITE - 5 MW TO 30 MW
(Continued)

SYSTEM:

COMPONENTS
- o Dam
- o Inlet Structure
- o Turbine
- o Generator
- o Transformers and Switchyard
- o Power Plant Structures
- o Transmission Lines
- o Access Roads

RUN-OF-RIVER OPERATION
UNDEVELOPED SITE - GREATER THAN 30 MW

SYSTEM:

GENERIC FEATURES

- Create new dam and reservoir
- Dam is normally less than 65 feet above stream bed
- Plant utilizes natural stream flow for power generation
- Reservoir has little storage capacity so plant operates at essentially constant level
- Water releases downstream of site are essentially unchanged from normal conditions.

CONSTRUCTION ACTIONS

- Exploration
- Construction of Access Roads
- Site Preparation
- Stream Diversion
- Reservoir Clearing
- Excavation
- Deposition of Spoils
- Dam Construction
- Switchyard Construction
- Transmission Lines Construction
- Accommodation of Work Force

OPERATION ACTIONS

- Surface Release
- Power Generation
- Maintenance

RESOURCES USED:

PLANT CHARACTERISTICS

- 100 MW Plant Capacity
- 40% Plant Factor
- 50 Years Service Life
- 85% Plant Efficiency
- 40 Feet Head
- 29.8×10^7 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	9.2 Million

LAND	Acres
o Area Occupies	
Power Plant	40
Reservoir	6000

COSTS	Dollars (1980)
o Construction ($2000/Kw)	$200.0 Million
o Operating and Maintenance	$ 24.2 Million (50 Year Life)
o Fishery Mitigation	$ 10.0 Million

PERSONNEL	Workers/Year
o Construction (5 Years)	320
o Operation and Maintenance	20

RUN-OF-RIVER OPERATION
UNDEVELOPED SITE - GREATER THAN 30 MW
(Continued)

SYSTEM:
COMPONENTS

- Dam
- Inlet Structure
- Turbine
- Generator
- Transformers and Switchyard
- Power Plant Structure
- Transmission Lines
- Access Roads

RUN-OF-RIVER OPERATION
EXISTING DAM - LESS THAN 5 MW

SYSTEM:

GENERIC FEATURES

- o Hydroelectric plant added to existing dam
- o Dam is normally less than 65 feet above stream bed
- o Plant utilizes natural stream flow for power generation
- o Reservoir has little storage capacity so plant operates at essentially constant level
- o Water releases downstream of site are essentially unchanged from normal conditions

CONSTRUCTION ACTIONS

- o Reservoir Dredging
- o Powerhouse Construction
- o Transmission Lines Construction
- o Accommodation of Work Force

OPERATING ACTIONS

- o Surface Release
- o Power Generation
- o Maintenance

COMPONENTS

- o Turbine
- o Generator
- o Transformer
- o Power Plant Structure

RESOURCES USED:

PLANT CHARACTERISTICS

- o 4 MW Plant Capacity
- o 40% Plant Factor
- o 50 Years Service Life
- o 83% Plant Efficiency
- o 40 Feet Head
- o 11.6×10^6 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	0.4 Million

LAND	Acres
o Area Occupied	
Power Plant	10
Reservoir	Existing

COSTS	Dollars (1980)
o Construction ($1,500/Kw)	$ 6.0 Million
o Operating and Maintenance	$ 2.7 Million
o Fishery Mitigation	$ 0.2 Million

PERSONNEL	Workers/Year
o Construction (1.0 Years)	40
o Operation and Maintenance	0.6

RUN-OF-RIVER OPERATION
EXISTING DAM - 5 MW TO 30 MW

SYSTEM:

GENERIC FEATURES

- o Hydroelectric plant added to an existing dam
- o Dam is normally less than 65 feet above stream bed
- o Plant utilizes natural stream flow for power generation
- o Reservoir has little storage capacity so plant operates at essentially constant level
- o Water releases downstream of site are essentially unchanged from normal conditions

CONSTRUCTION ACTIONS

- o Exploration
- o Site Preparation
- o Reservoir Dredging
- o Excavation
- o Deposition of Spoils
- o Powerhouse Construction
- o Switchyard Construction
- o Transmission Lines Construction
- o Accommodation or Work Force

OPERATION ACTIONS

- o Surface Release
- o Power Generation
- o Maintenance

COMPONENTS

- o Turbine
- o Generator
- o Transformers and Switchyard
- o Power Plant Structure
- o Transmission Lines

RESOURCES USED:

PLANT CHARACTERISTICS

- o 30 MW Plant Capacity
- o 40% Plant Factor
- o 50 Years Service Life
- o 85% Plant Efficiency
- o 40 Feet Head
- o 89.4 x 10^6 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	2.7 Million

LAND	Acres
o Area Occupied	
Power Plant	20
Reservoir	Existing

COSTS	Dollars (1980)
o Construction ($1,500/Kw)	$ 45.0 Million
o Operating and Maintenance	$ 7.0 Million (50 Year Life)
o Fishery Mitigation	$ 1.4 Million

PERSONNEL	Workers/Year
o Construction (2.5 Years)	140
o Operation and Maintenance	1.5

RUN-OF-RIVER OPERATION
EXISTING DAM - GREATER THAN 30 MW

SYSTEM:

GENERIC FEATURES

- o Hydroelectric plant added to existing dam
- o Dam is normally less than 65 feet above stream bed
- o Plant Utilizes natural stream flow for power generation
- o Reservoir has little storage capacity so plant operates at essentially constant level
- o Water releases downstream of site are essentially unchanged from normal conditions

CONTRUCTION ACTIONS

- o Exploration
- o Site Preparation
- o Reservoir Dredging
- o Excavation
- o Deposition of Spoils
- o Powerhouse Construction
- o Switchyard Construction
- o Transmission Lines Construction
- o Accommodation of Work Force

OPERATION ACTIONS

- o Surface Release
- o Power Generation
- o Maintenance

COMPONENTS

- o Turbine
- o Generator
- o Transformers and Switchyard
- o Power Plant Structure
- o Transmission Lines

RESOURCES USED:

PLANT CHARACTERISTICS

- o 100 MW Plant Capacity
- o 40% Plant Factor
- o 50 Year Service Life
- o 85% Plant Efficiency
- o 40 Feet Head
- o 29.8 x 10^7 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	9.2 Million

LAND	Acres
o Area Occupied	
Power Plant	40
Reservoir	Existing

COSTS	Dollars (1980)
o Construction ($1,500/Kw)	$150.0 Million
o Operating and Maintenance	$ 24.0 Million
o Fishery Mitigation	$ 4.5 Million

PERSONNEL	Workers/Year
o Construction (4 Years)	300
o Operation and Maintenance	20

STORAGE OPERATION
UNDEVELOPED SITE - LESS THAN 5 MW

SYSTEM:

GENERIC FEATURES

- o Create new dam and reservoir
- o Dam is normally greater than 65 feet above streambed
- o Plant is used for both base-load power generation and peaking operations
- o Streamflow is stored during off-peak times and released at high flow rates during peak times
- o Reservoir levels fluctuate frequently
- o Downstream constraints may require that a re-regulating reservoir be created to adjust for downstream fluctuations

CONSTURCTION ACTIONS

- o Exploration
- o Construction of Access Roads
- o Site Preparation
- o Stream Diversion
- o Reservoir Clearing
- o Excavation
- o Deposition of Spoils
- o Creation of Borrow Pits
- o Dam Construction
- o Powerhouse Construction
- o Transmission Lines Construction
- o Accommodation of Work Force

OPERATION ACTIONS

- o Impoundment and Creation of a Man-Made Lake
- o Turbine Release
- o Power Generation
- o Maintenance

RESOURCES USED:

PLANT CHARACTERISTICS

- o 4 MW Plant Capacity
- o 25% Plant Factor
- o 50 Year Service Life
- o 85% Plant Efficiency
- o 100 Feet Head
- o 7.4×10^6 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	0.1 Million

LAND	Acres
o Area Occupied	
Power Plant	10
Reservoir	500

COSTS	Dollars
o Construction ($2,600/Kw)	$10.4 Million
o Operating and Maintenance	$ 2.78 Million (50 Year Life)
o Fishery Mitigation	$ 1.0 Million

PERSONNEL	Workers/Year
o Construction	40
o Operation and Maintenance	0.6

RUN OF RIVER OPERATION
UNDEVELOPED SITE - LESS THAN 5 MW
(Continued)

SYSTEM:

COMPONENTS

- o Dam and Reservoir
- o Spillway
- o Intake Penstocks
- o Turbine
- o Generators
- o Power Plant Structure

STORAGE OPERATION
UNDEVELOPED SITE - 5 MW TO 30 MW

SYSTEM:

GENERIC FEATURES

- o Create new dam and reservoir
- o Dam is normally greater than 65 feet above stream bed
- o Plant is used for both base-load power generation and peaking operations
- o Streamflow is stored during off-peak times and released at high flow rates during peak times
- o Reservoir levels fluctuate frequently
- o Downstream constraints may require that a re-regulating reservoir be created to adjust for downstream fluctuations

CONSTRUCTION ACTIONS

- o Exploration
- o Construction of Access Roads
- o Site Preparation
- o Stream Diversion
- o Reservoir Clearing
- o Excavation
- o Deposition of Spoils Area
- o Creation of Borrow Pits
- o Dam Construction
- o Powerhouse Construction
- o Switchyard Construction
- o Transmission Lines Construction
- o Accommodation of Work Force

OPERATION ACTIONS

- o Impoundment and Creation of a Man-Made Lake
- o Turbine Release
- o Maintenance

RESOURCES USED:

PLANT CHARACTERISTICS

- o 30 MW Plant Capacity
- o 25% Plant Factor
- o 50 Year Service Life
- o 85% Plant Efficiency
- o 100 Feet Head
- o 55.8×10^6 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	0.7 Million

LAND	Acres
o Area Occupied	
Power Plant	20
Reservoir	2000

COSTS	Dollars (1980)
o Construction ($2,600/Kw)	$78.0 Million
o Operating and Maintenance	$ 7.0 Million (50 Year Life)
o Fishery Mitigation	$ 7.8 Million

STORAGE OPERATION
UNDEVELOPED SITE - 5 MW TO 30 MW
(Continued)

SYSTEM:

COMPONENTS

- o Dam and Reservoir
- o Re-regulating Dam and Reservoir
- o Spillway
- o Intake Penstocks
- o Turbine
- o Generators
- o Transformers and Switchyard
- o Power Plant Structure
- o Access Roads

RESOURCES USED:

PERSONNEL	Workers/Year
o Construction (4 Years)	160
o Operation and Maintenance	1.5

STORAGE OPERATION
UNDEVELOPED SITE - GREATER THAN 30 MW

SYSTEM:

GENERIC FEATURES

- o Create new dam and reservoir
- o Dam is normally greater than 65 feet above streambed
- o Plant is used for both base-load power generation and peaking operations
- o Streamflow is stored during off-peak times and released at high flow rates during peak times
- o Reservoir levels fluctuate frequently
- o Downstream constraints may require that a re-regulating reservoir be created to adjust for downstream fluctuations

CONSTRUCTION ACTIONS

- o Exploration
- o Construction of Access Roads
- o Site Preparation
- o Stream Diversion
- o Reservoir Clearing
- o Excavation
- o Deposition of Spoils Area
- o Creation of Borrow Pits
- o Dam Construction
- o Powerhouse Construction
- o Switchyard Construction
- o Transmission Lines Construction
- o Accommodation of Work Force

RESOURCES USED:

PLANT CHARACTERISTICS

- o 100 MW Plant Capacity
- o 25% Plant Factor
- o 50 Year Service Life
- o 85% Plant Efficiency
- o 100 Feet Head
- o 18.6×10^7 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	2.3 Million

LAND	Acres
o Area Occupied	
Power Plant	40
Reservoir	6000

COSTS	Dollars (1980)
o Construction ($2,600/Kw)	$260 Million
o Operating and Maintenance	$ 24.2 Million (50 Year Life)
o Fishery Mitigation	$ 10.0 Million

STORAGE OPERATION
UNDEVELOPED SITE - GREATER THAN 30 MW
(Continued)

SYSTEM:

OPERATION ACTIONS

- o Impoundment and Creation of a Man-Made Lake
- o Turbine Release
- o Maintenance

COMPONENTS

- o Dam and Reservoir
- o Re-regulating Dam and Reservoir
- o Spillway
- o Intake Penstocks
- o Turbine
- o Generators
- o Transformers and Switchyard
- o Power Plant Structure
- o Access Roads

RESOURCES USED:

PERSONNEL	Workers/Year
o Construction (5 Years)	420
o Operation and Maintenance	20

STORAGE OPERATION
EXISTING DAM - LESS THAN 5 MW

SYSTEM:

GENERIC FEATURES

- o Dam is normally greater than 65 feet above streambed
- o Plant is used for both base-load power generation and peaking operations
- o Streamflow is stored during off-peak times and released at high flow rates during peak times
- o Reservoir levels fluctuate frequently
- o Downstream constraints may required that a re-regulating reservoir be created to adjust for downstream fluctuation

CONSTRUCTION ACTIONS

- o Reservoir Dreging
- o Powerhouse Construction
- o Accommodation of Work Force

OPERATION ACTIONS

- o Impoundment and Creation of a Man-Made Lake
- o Turbine Release
- o Power Generation
- o Maintenance

COMPONENTS

- o Dam and Reservoir
- o Spillway
- o Intake Penstocks
- o Turbine
- o Generators
- o Power Plant Structure

RESOURCES USED:

PLANT CHARACTERISTICS

- o 4 MW Plant Capacity
- o 25% Plant Factor
- o 50 Year Service Life
- o 85% Plant Efficiency
- o 100 Feet Head
- o 7.4 x 10^6 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	0.1 Million

LAND	Acres
o Area Occupied	
Power Plant	10
Reservoir	Existing

PERSONNEL	Workers/Year
o Construction (1.0 Years)	40
o Operation and Maintenance	0.6

STORAGE OPERATION
EXISTING DAM - 5 MW TO 30 MW

SYSTEM:

GENERIC FEATURES

- Dam is normally greater than 65 feet above streambed
- Plant is used for both base-load power generation and peaking operations
- Streamflow is stored during off-peak times and released at high flow rates during peak times
- Reservoir levels fluctuate frequently
- Downstream constraints may require that a re-regulating reservoir be created to adjust for downstream fluctuation

CONSTRUCTION ACTIONS

- Exploration
- Site Preparation
- Reservoir Dredging
- Excavation
- Deposition of Spoils
- Powerhouse Construction
- Switchyard Construction
- Transmission Lines Construction
- Accommodation of Work Force

OPERATION ACTIONS

- Impoundment and Creation of a Man-Made Lake
- Turbine Release
- Power Generation
- Maintenance

RESOURCES USED:

PLANT CHARACTERISTICS

- 30 MW Plant Capacity
- 25% Plant Factor
- 50 Year Service Life
- 85% Plant Efficiency
- 100 Feet Head
- 55.8 x 10^6 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	0.7 Million

LAND	Acres
o Area Occupied	
Power Plant	20
Reservoir	Existing

COSTS	Dollars (1980)
o Construction ($1,700/Kw)	$51.0 Million
o Operating and Maintenance	$ 7.0 Million (50 Year Life)
o Fishery Mitigation	$ 1.5 Million

PERSONNEL	Workers/Year
o Construction (2.5 Years)	140
o Operation and Maintenance	1.5

STORAGE OPERATION
EXISTING DAM - 5 MW TO 30 MW
(Continued)

SYSTEM:

COMPONENTS

- o Dam and Reservoir
- o Re-regulating Dam and Reservoir
- o Spillway
- o Turbine
- o Generators
- o Transformers and Switchyard
- o Transmission Lines
- o Power Plant Structure

STORAGE OPERATION
EXISTING DAM - GREATER THAN 30 MW

SYSTEM:

GENERIC FEATURES

- Dam is normally greater than 65 feet above streambed
- Plant is used for both base-load power generation and peaking operations
- Streamflow is stored during off-peak times and released at high flow rates during peak times
- Reservoir levels fluctuate frequently
- Downstream constraints may require that a re-regulating reservoir be created to adjust for downstream fluctuation

CONSTRUCTION ACTIONS

- Exploration
- Site Preparation
- Reservoir Dredging
- Excavation
- Deposition of Spoils
- Powerhouse Construction
- Switchyard Construction
- Transmission Lines Construction
- Accommodation of Work Force

OPERATION ACTIONS

- Impoundment and Creation of a Man-Made Lake
- Turbine Release
- Power Generation
- Maintenance

RESOURCES USED:

PLANT CHARACTERISTICS

- 100 MW Plant Capacity
- 25% Plant Factor
- 50 Year Service Life
- 85% Plant Efficiency
- 100 Feet Head
- 18.6×10^7 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	2.3 Million

LAND	Acres
o Area Occupied	
Power Plant	40
Reservoir	Existing

COSTS	Dollars (1980)
o Construction ($1,700/Kw)	$ 170.0 Million
o Operating and Maintenance	$ 24.2 Million (50 Year Life)
o Fishery Mitigation	$ 5.1 Million

PERSONNEL	Workers/Year
o Construction (4 Years)	340
o Operation and Maintenance	20

STORAGE OPERATION
EXISTING DAM - GREATER THAN 30 MW
(Continued)

SYSTEM:

COMPONENTS

- Dam and Reservoir
- Re-regulating Dam and Reservoir
- Spillway
- Intake Penstocks
- Turbine
- Generators
- Transformers and Switchyard
- Transmission Lines
- Power Plant Structure

CONDUIT
EXISTING DAM OR CHANNEL - LESS THAN 5 MW

SYSTEM:

GENERIC FEATURES

- o Hydroelectric plant supplied by or added to a man-made channel
- o Dam is normally less than 65 feet above channel bed
- o Plant utilizes existing channel flow for power generation
- o Water releases downstream of site are essentially unchanged from normal conditions
- o A diversion dam and power tunnel may be required
- o Stream may be dewatered between dam and powerhouse

CONSTRUCTION ACTIONS

- o Powerhouse Construction
- o Transmission Lines Construction
- o Accommodation of Work Force

OPERATION ACTIONS

- o Power Generation
- o Maintenance

COMPONENTS

- o Diversion Dam and Reservoir
- o Inlet Structure
- o Turbine
- o Generator
- o Transformer
- o Power Plant Structure
- o Transmission Lines

RESOURCES USED:

PLANT CHARACTERISTICS

- o 4 MW Plant Capacity
- o 60% Plant Factor
- o 50 Year Service Life
- o 83% Plant Efficiency
- o 20 Feet Head
- o 17.4×10^6 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	1.2×10^6

LAND	Acres
o Area Occupied	
Power Plant	10
Reservoir	None

COSTS	Dollars (1980)
o Construction ($1,000/Kw)	$ 4.0 Million
o Operating and Maintenance	$ 2.7 Million (50 Year Life)
o Fishery Mitigation	Minimal

PERSONNEL	Workers/Year
o Construction (1 Year)	30
o Operation and Maintenance	0.6

CONDUIT
EXISTING DAM OR CHANNEL - 5 MW TO 30 MW

SYSTEM:

GENERIC FEATURES

- o Hydroelectric plant supplied by or added to a man-made channel
- o Dam is normally less than 65 feet above channel bed
- o Plant utilizes existing channel flow for power generation
- o Water releases downstream of site are essentially unchanged from normal conditions
- o Stream may be dewatered between dam and powerhouse
- o A diversion dam and power tunnel may be required

CONTRUCTION ACTIONS

- o Excavation
- o Spoils Area
- o Powerhouse Construction
- o Switchyard Construction
- o Transmission Lines
- o Accommodation of Work Force

OPERATIONS ACTIONS

- o Power Generation
- o Maintenance

COMPONENTS

- o Diversion Dam and Reservoir
- o Inlet Structure
- o Turbine
- o Generator
- o Transformers and Switchyard
- o Power Plant Structure
- o Transmission Lines

RESOURCES USED:

PLANT CHARACTERISTICS

- o 30 MW Plant Capacity
- o 60% Plant Factor
- o 50 Year Service Life
- o 85% Plant Efficiency
- o 40 Feet Head
- o 13.4×10^7 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	4.1 Million
LAND	**Acres**
o Area Occupied	
Power Plant	20
Reservoir	None
COSTS	**Dollars (1980)**
o Construction ($1,000/Kw)	$ 30.0 Million
o Operating and Maintenance	$ 7.0 Million
o Fishery Mitigation	Minimal
PERSONNEL	**Workers/Year**
o Construction (2 Years)	120
o Operation and Maintenance	1.5

CONDUIT

EXISTING DAM OR CHANNEL CONDUIT - GREATER THAN 30 MW

SYSTEM:

GENERIC FEATURES

- Hydroelectric plant supplied by or added to a man-made channel
- Dam is normally less than 65 feet above channel bed
- Plant utilizes existing channel flow for power generatin
- Water releases downstream of site are essentially unchanged from normal conditions
- A diversion dam and power tunnel may be required
- Stream may be dewatered between dam and powerhouse

CONSTRUCTION ACTIONS

- Excavation
- Disposition of Spoils
- Powerhouse Construction
- Switchyard Construction
- Transmission Lines Construction
- Accommodation of Work Force

OPERATION ACTIONS

- Power Generation
- Maintenance

COMPONENTS

- Diversion Dam and Reservoir
- Inlet Structure
- Turbine
- Generator
- Transformers and Switchyard
- Power Plant Structure
- Transmission Lines

RESOURCES USED:

PLANT CHARACTERISTICS

- 100 MW Plant Capacity
- 40% Plant Factor
- 50 Year Service Life
- 85% Plant Efficiency
- 40 Feet Head
- 29.8×10^7 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	9.2 Million

LAND	Acres
o Area Occupied	
Power Plant	40
Reservoir	2000

COSTS	Dollars (1980)
o Construction ($2,000/Kw)	$ 200.0 Million
o Operating and Maintenance	$ 24.0 Million
o Fishery Mitigation	$ 4.5 Million

PERSONNEL	Workers/Year
o Construction (2 Years)	340
o Operation and Maintenance	20

CONDUIT
UNDEVELOPED - LESS THAN 5 MW

SYSTEM:

GENERIC FEATURES

- Hydroelectric plant supplied by a man-made channel
- Dam is normally less than 65 feet above channel level
- Plant is used for both base-load power generation and peaking operations
- Streamflow is stored during off-peak times and released at high flow rates during peak times
- Reservoir levels fluctuate frequently
- Stream may be dewatered between dam and powerhouse

CONTRUCTION ACTIONS

- Powerhouse Construction
- Transmission Lines
- Accommodation of Work Force

OPERATION ACTIONS

- Power Generation
- Maintenance

COMPONENTS

- Dam and Reservoir
- Diversion Dam and Reservoir
- Spillway
- Intake Penstocks
- Turbine
- Generators
- Power Plant Structure

RESOURCES USED:

PLANT CHARACTERISTICS

- 4 MW Plant Capacity
- 25% Plant Factor
- 50 Year Service Life
- 83% Plant Efficiency
- 40 Feet Head
- 7.27 x 10^6 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	0.2 Million
LAND	**Acres**
o Area Occupied	
Power Plant	10
Reservoir	500
COSTS	**Dollars (1980)**
o Construction ($1,500/Kw)	$ 6 Million
o Operating and Maintenance	$ 2.7 Million (50 Year Life)
o Fishery Mitigation	Minimal
PERSONNEL	**Workers/Year**
o Construction (1.5 Years)	30
o Operation and Maintenance	0.6

CONDUIT
UNDEVELOPED - 5 MW TO 30 MW

SYSTEM:

GENERIC FEATURES

- Hydroelectric plant supplied by a man-made channel
- Dam is normally less than 65 feet above channel bed
- Plant is used for both base-load power generation and peaking operations
- Streamflow is stored during off-peak times and released at high flow rates during peak times
- Reservoir levels fluctuate frequently
- Downstream constraints may require that a re-regulating reservoir be created to adjust for downstream fluctuation
- Stream may be dewatered between dam and powerhouse

CONSTRUCTION ACTIONS

- Excavation
- Spoils Area
- Powerhouse Construction
- Switchyard Construction
- Transmission Lines
- Accommodation of Work Force

OPERATION ACTIONS

- Power Generation
- Maintenance

RESOURCES USED:

PLANT CHARACTERISTICS

- 30 MW Plant Capacity
- 25% Plant Factor
- 50 Year Service Life
- 85% Plant Factor
- 40 Feet Head
- 55.8 x 10^6 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	1.7 Million

LAND	Acres
o Area occupied	
Power plant	20
Reservoir	2000

COSTS	Dollars (1980)
o Construction ($1,700/Kw)	$51.0 Million
o Operating and Maintenance	$ 7.0 Million (50 Year Life)
o Fishery Mitigation	Minimal

PERSONNEL	Workers/Year
o Construction (3 Years)	120
o Operation and Maintenance	1.5

CONDUIT
UNDEVELOPED - 5 MW TO 30 MW
(Continued)

SYSTEM:

COMPONENTS

- o Dam and Reservoir
- o Diversion Dam and Reservoir
- o Re-regulating Dam and Reservoir
- o Spillway
- o Intake Penstocks
- o Turbine
- o Generators
- o Transformers and Switchyard
- o Transmission Lines
- o Power Plant Structure

CONDUIT
UNDEVELOPED - GREATER THAN 30 MW

SYSTEM:

GENERIC FEATURES

- o Hydroelectric plant supplied by a man-made channel
- o Dam is normally less than 65 feet above channel bed
- o Plant is used for both base-load power generation and peaking operations
- o Streamflow is stored during off-peak times and released at high flow rates during peak times
- o Reservoir levels fluctuate frequently
- o Downstream constraints may require that a re-regulating reservoir be created to adjust for downstream fluctuation
- o A diversion dam and power tunnel may be required
- o Stream may be dewatered between dam and powerhouse

CONSTRUCTION ACTIONS

- o Excavation
- o Deposition of Spoils
- o Powerhouse Construction
- o Switchyard Construction
- o Transmission Lines Construction
- o Accommodation of Work Force

OPERATION ACTIONS

- o Power Generation
- o Maintenance

RESOURCES USED:

PLANT CHARACTERISTICS

- o 100 MW Plant Capacity
- o 25% Plant Factor
- o 50 Year Service Life
- o 85% Plant Factor
- o 100 Feet Head
- o 18.6×10^7 kwh/Year Energy Production

FUEL	Acre - ft.
o Water	2.3 Million

LAND	Acres
o Area Occupied	
Power Plant	40
Reservoir	2000

COSTS	Dollars (1980)
o Construction ($2,600/Kw)	$260.0 Million
o Operating and Maintenance	$ 7.0 Million (50 Year Life)
o Fishery Mitigation	$ 4.5 Million

PERSONNEL	Workers/Year
o Construction (4 Years)	340
o Operation and Maintenance	20

CONDUIT
UNDEVELOPED - GREATER THAN 30 MW
(Continued)

SYSTEM:

COMPONENTS

- o Diversion Dam and Reservoir
- o Re-regulating Dam and Reservoir
- o Spillway
- o Intake Penstocks
- o Turbine
- o Generators
- o Transformers and Switchyard
- o Transmission Lines
- o Power Plant Structure

APPENDIX D

SELECTION OF REGIONAL STUDY AREAS

The United States has been subdivided into regions in several ways for many purposes. For example, the National Electric Reliability Council is subdivided into nine regions based on utility power pools and electrical transmission grids (Figure D.1). The Corps regional plans for the National Hydropower Study use these boundaries. The U.S. Fish and Wildlife Service is subdivided into six regions primarily based on similar types of habitat (Figure D.2). The nation is also subdivided into natural major drainage basins (Figure D.3). The U.S. Water Resources Council uses these regions to aggregate water supply and water quality data and to form bounderies for river basin commissions, interagency committees, and interstate river basin compacts. Each of these regional groupings has some significance for assessing the environmental impacts of hydropower development and could have been used to define regions for this study.

The two most important considerations for defining study areas for this report are: 1) similarity in environmental characteristics and 2) similarity in the type and amount of hydropower potential. Broad ecoregions defined by the U.S. Department of the Interior (1976) (Figure D.4), represent areas with similar environmental characteristics.

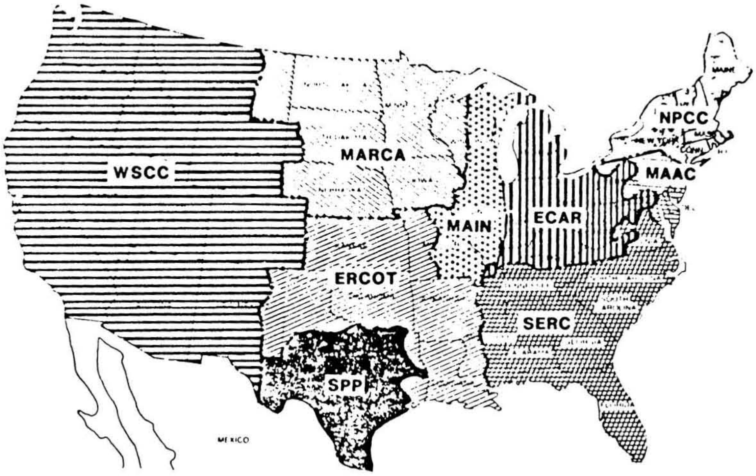


Figure D.1 NATIONAL ELECTRIC RELIABILITY COUNCIL REGIONS

Figure D.2 FISH AND WILDLIFE SERVICE REGIONS

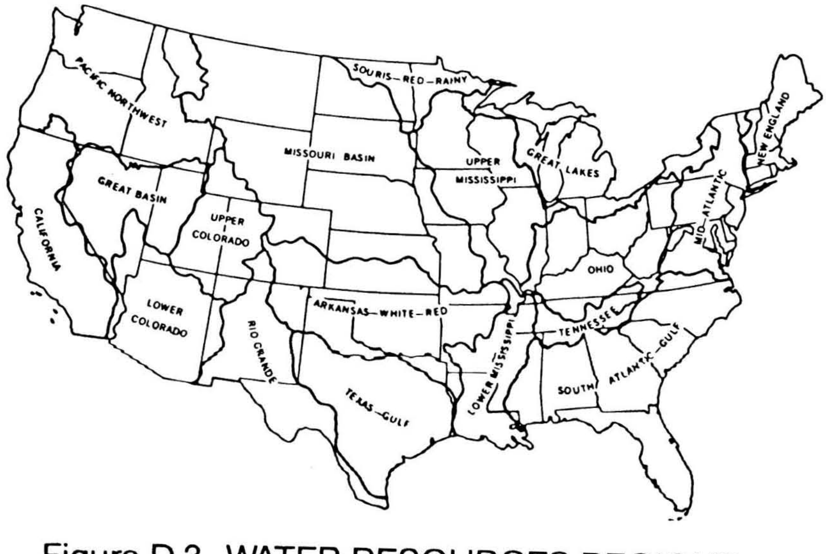
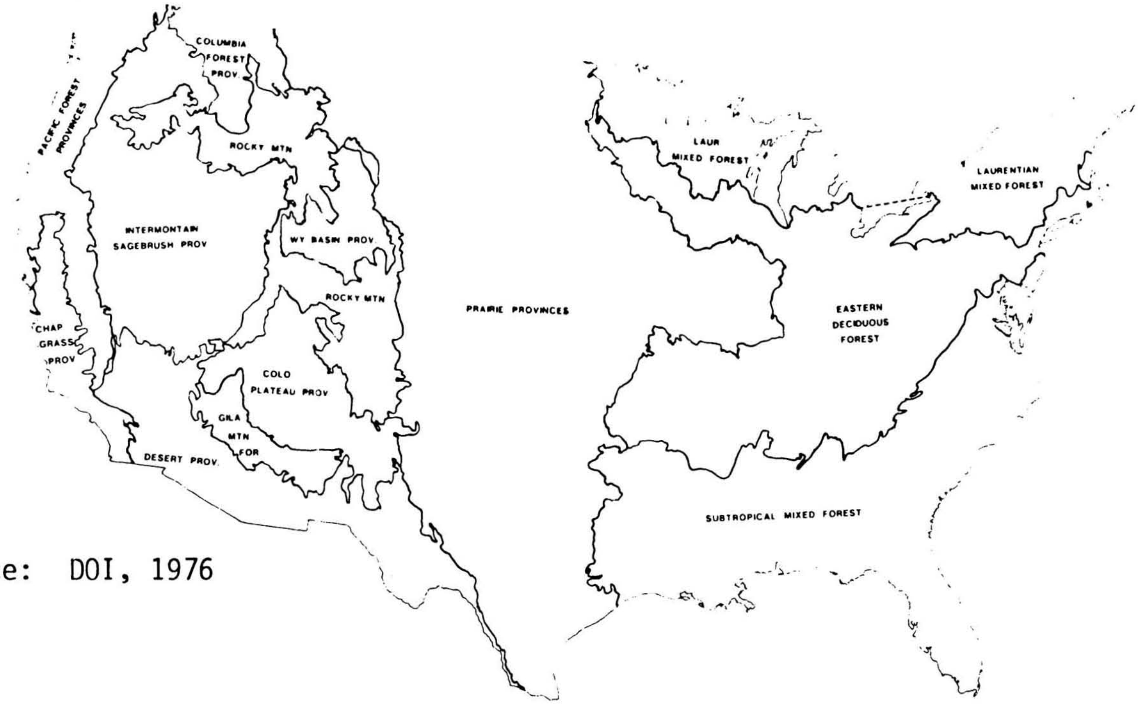
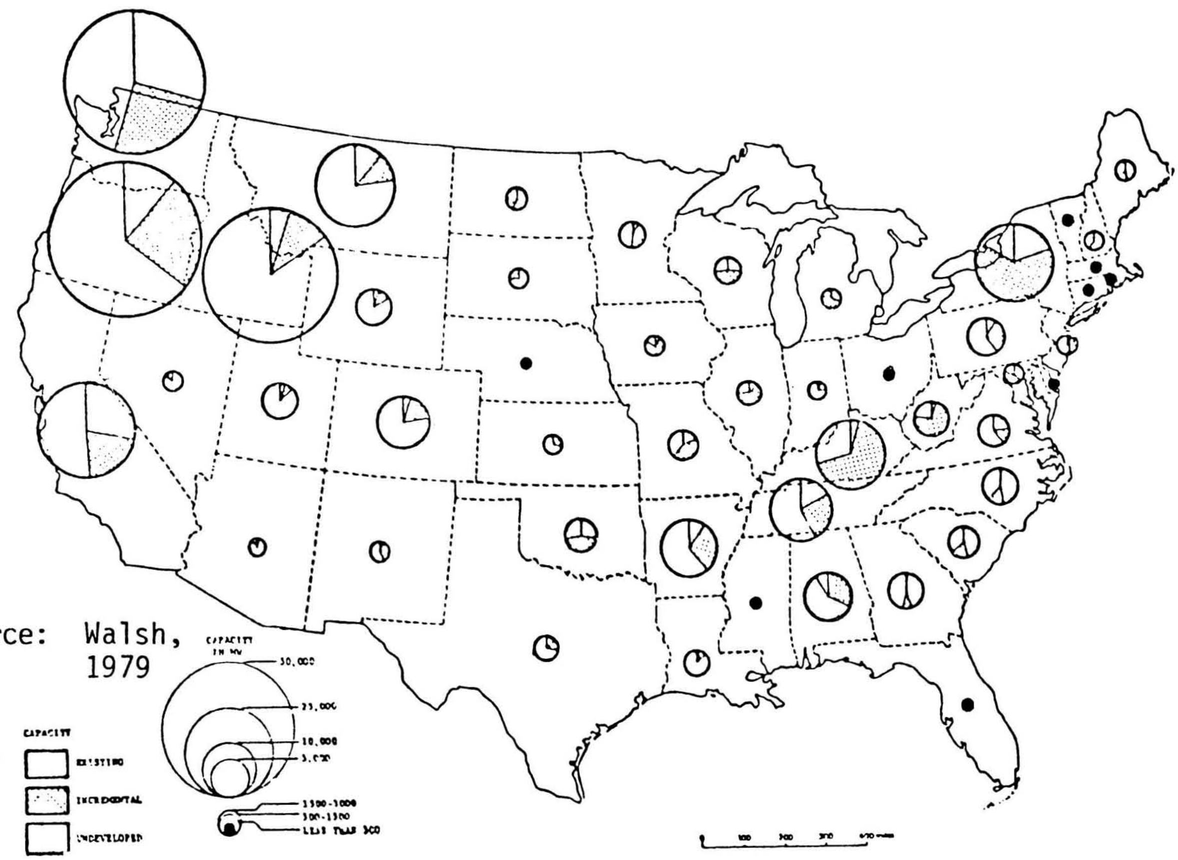


Figure D.3 WATER RESOURCES REGIONS



Source: DOI, 1976

Figure D.4 ECOREGIONS OF THE UNITED STATES



Source: Walsh, 1979

Figure D.5 NATIONAL HYDROELECTRIC POWER RESOURCES

The type and amount of hydropower potential throughout the country is summarized in Figure D.5. Two generalizations are evident from the distribution. First, the hydropower potential is concentrated in the Pacific Northwest, California, and the Appalachian states. Second, in the western states, hydropower potential in predominantly at undeveloped sites; and in the eastern states, hydropower potential is predominantly at existing dam sites. The regions for this study (Figure D.6) were formed by using the ecoregions as a primary guide and then grouping states with similar hydropower potential. State boundaries were maintained recognizing state statutory and regulatory differences and to simplify data acquisition and agency review.

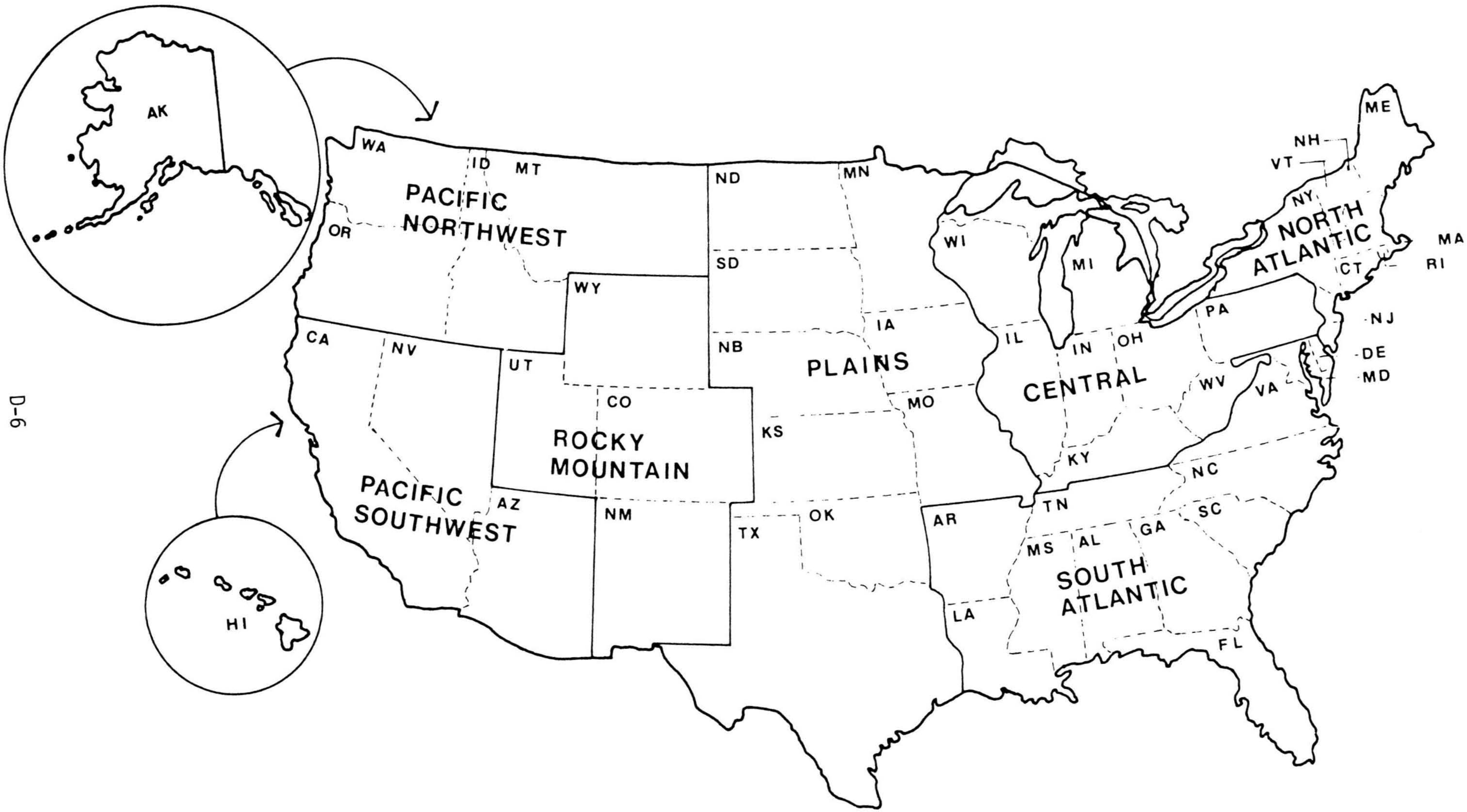


Figure D.6 REGIONAL STUDY AREAS

APPENDIX E

REGIONAL QUESTIONNAIRES

The U. S. Army Corps of Engineers District offices were surveyed to verify the regional distinctions described in Chapter V (See INTASA, Inc. 1980b). Potential impacts under each of the four environmental factors (water quality and use, aquatic ecology, terrestrial ecology, and land use) were suggested for different hydropower configurations. Reviewers were asked to rate these short term and long term impacts from -10, the most adverse impact, to +10, the most beneficial impact, with a zero rating indicating that the impact is insignificant. One of the following degrees of regional distinction was also requested for each impact: (1) unique to the region, (2) occurs in adjacent regions, or (3) common to most regions. Space was available to suggest additional impacts and to record comments. The suggested potential impacts varied among regions according to perceived environmental differences. A sample questionnaire for the Pacific Northwest region is displayed in Figure E.1. The results of the questionnaires are summarized in Table E-1. The number of responses and the most adverse and the most beneficial impact under each of the four environmental factors are indicated for each region.

NATIONAL ENVIRONMENTAL HYDROPOWER ASSESSMENT

PACIFIC NORTHWEST

POTENTIAL IMPACTS	DAM TYPES (E-Existing site; U-Undeveloped site)					SIGNIFICANCE OF IMPACTS (Rate from -10 to +10 with -10 the most adverse rating, +10 the most beneficial & 0 insignificant)		REGIONAL DISTINCTION			COMMENTS
	STORAGE		RUN-OF-RIVER		CONDUIT						
	< 30 MW	> 30 MW	< 30 MW	> 30 MW		Short term < 2 yrs	Long term > 2 yrs	Unique to region	Occurs in adjacent regions	Common to most regions	
WATER QUALITY AND USE											
Daily, seasonal & yearly downstream fluctuations	E / U	E / U	E / U	E / U	E / U						
Thermal stratification if deep reservoir	U	U		U							
Spring and fall turnover results in surges of salts, nutrients, etc.	E / U	E / U	E / U	E / U	E / U						
Exposure of reservoir shoreline	E / U	E / U	E / U	E / U							
Alteration of flow regime	E / U	E / U	E / U	E / U	E / U						
Increased nitrogen content downstream	E / U	E / U	E / U	E / U							
Other:											
AQUATIC ECOLOGY											
Loss of spawning beds	U	U	U	U	U						
Loss of riparian edge	U	U	U	U	U						
Blocking of anadromous fish run	U	U	U	U	U						
Fish mortality due to turbine passage	E / U	E / U	E / U	E / U	E / U						
Loss of fish due to nitrogen narcosis	U	U	U	U							
Other:											
Other:											
TERRESTRIAL ECOLOGY											
Displacement of indigenous wildlife	U	U	U	U	U						
Loss of riverine wildlife	U	U	U	U	U						
Establishment of new plant species	U	U	U	U	U						
Temporary/permanent loss of wildfowl and riverine hunting	U	U	U	U	U						
Loss of plant species	U	U	U	U	U						
Loss of wetlands	U	U	U	U	U						
Other:											
LAND USE											
Degradation of water-based recreational activities	E / U	E / U	E / U	E / U	E / U						
Visual impairment	E / U	E / U	E / U	E / U	E / U						
Loss of existing recreational activities for undeveloped sites	U	U	U	U	U						
Alteration of existing fisheries	E / U	E / U	E / U	E / U	E / U						
Loss of recreation on shorelines	U	U	U	U	U						
Social, economic effects from construction work force	E / U	E / U	E / U	E / U	E / U						
Other:											
Other:											

PLEASE RETURN MARKED QUESTIONNAIRE, BY NOVEMBER 15, 1980 TO MARK TREMBLEY, EDAW INC., 50 GREEN STREET, SAN FRANCISCO, CA., 94111. IF YOU HAVE ANY QUESTIONS, PLEASE FEEL FREE TO CALL (415)433-1484

Figure E.1 SAMPLE QUESTIONNAIRE (PACIFIC NORTHWEST)

TABLE E-1. SUMMARY OF QUESTIONNAIRE RESULTS

Region	Number of Responses	Water Quality and Use		Aquatic Ecology		Terrestrial Ecology		Land Use	
		Most Adverse	Most Benef.	Most Adverse	Most Benef.	Most Adverse	Most Benef.	Most Adverse	Most Benef.
Pacific Northwest	1	Alteration of Flow Regime	NL*	. Loss of Spawning Beds . Blocking of Anadromous Fish . Fish Mortality from Turbines	NL	Loss of Wetlands	Establish New Plant Species	Visual Impairment from Trans-mission lines	NL
Pacific Southwest	1	Downstream Water Level Fluctuations	Increase in Local Water Supply	Blocking of Anadromous Fish	NL	Rehabilitation of Wetlands	NL	Loss of Wilderness Character	NL
Rocky Mountain	1	.High Reservoir Evaporation Rate .Alteration of Streamflows	Increase in Local Water Supply	Loss of Cold Water Fishing	Increase in Flat Water Fishing	Loss of Riparian Edge	NL	Loss of Wilderness Character	Increase in Flat-Water Recreation
Plains	4	Downstream Water Level Fluctuations	Increase in Local Water Supply	Loss of Spawning Beds	Increase in Warm Water Fishing	Loss of Riparian Edge	NL	.Loss of Navigation Route .Conversion of Existing Land uses	Increase in Flat-Water Recreation

TABLE E-1. SUMMARY OF QUESTIONNAIRE RESULTS
(Continued)

Region	Number of Responses	Water Quality and Use		Aquatic Ecology		Terrestrial Ecology		Land Use	
		Most Adverse	Most Benef.	Most Adverse	Most Benef.	Most Adverse	Most Benef.	Most Adverse	Most Benef.
Central	4	.Low DO in Hypolimnion .Potential for Eutrophication	NL	Blocking of Anadromous Fish	Increase in Flat Water Fishing	Displacement of Indigenous Wildlife	NL	.Removal or Loss of Residences .Degradation of Water-Based Recrea.	Increase in Flat Water Recreation
North Atlantic	2	.Potential for Reservoir Siltation	NL	Blocking of Anadromous Fish	NL	.Displacement of Indigenous Wildlife .Disruption of Migratory Patterns .Loss of Endangered species .Loss of Wetlands	NL	Loss of White Water Recreation	NL
South Atlantic	4	.Downstream Water Level Fluctuations	NL	Blocking of Anadromous Fish	Increase in Warm Water Fish Species	.Destruction of Riverine Habitat .Loss of Riverine Wildlife	NL	Loss of Existing Recreational Activities	NL

* NL = None Listed.

APPENDIX F

ENVIRONMENTAL MATRICES

APPENDIX G

ENVIRONMENTAL LEGISLATION

Note: The following source material was reviewed in preparing this section: Brown and Buxton, 1978, 1979a, and 1979b; Brown and Ringo, 1979; Brown and Wilson, 1979; Cronmiller et al, 1979: EPA, 1980; FERC, 1979, FPC, 1974; Gladwell and Warnick, 1978; Gore, 1980a, 1980b, and 1980c; IWR, 1979; Natural Resources Law Institute, 1980; Oliver, 1975; Radzik and Reynolds, 1979; Reynolds, 1980a and 1980b; Schulthess, 1980; Corps, 1979; U.S. Fish and Wildlife Service, 1977; U.S. Senate, 1980.

Act:

Archaeological and Historical Preservation Act of 1974 (PL 93-291).

Implementing Agencies:

Heritage Conservation and Recreation Service, State Historic Preservation Officer, and Advisory Council on Historic Preservation.

Action:

Review

Purpose:

The Act is intended to preserve historic and archaeological data which might otherwise be irreparably lost or destroyed as a result of any federal construction project or federally licensed activity or program.

Relevance to Hydropower:

If a project will cause irreparable damage, loss, or destruction of significant archaeological data, the responsible federal official is authorized to undertake activities to recover and preserve the data. A provision of the Act allows construction agencies to request the Secretary of the Interior to undertake a survey and finance the survey with public funds. An EIS may have to be prepared if the proposed project will have an effect on material having historical, cultural, or archaeological value. The State Historic Preservation Officer or Archaeological officer can request that an archaeological survey be undertaken before the FERC license is issued or a federal project begun.

Act:

The Clean Air Act (PL 91-604; PL 95-95).

Implementing Agencies:

U.S. Environmental Protection Agency, state air quality agencies.

Action:

Permit, review.

Purpose:

The purpose of the Act is to establish a national commitment to protecting and preserving the quality of the nation's air.

Relevance to Hydropower:

The Act requires that point-source polluters obtain permits from the designated state agency or EPA. In designated areas, such as wilderness or national parks, the law does not allow any significant deterioration of clean air. Regarding the construction activities at a hydro site, guidance on dust control is usually included in the construction permit or the Section 404 permit from the Corps. There is no standard for controlling the release of dust from large-scale construction sites.

Act:

Clean Water Act (PL 95-217).

Implementing Agencies:

Environmental Protection Agency, Army Corps of Engineers, state water quality agencies.

Action:

Permits.

Purpose:

Congress made water pollution control a major legislative concern during the 1970's. The Clean Water Act of 1977 revised the Federal Water Pollution Control Act Amendments of 1972. Both laws have tremendously expanded the involvement of the federal government in controlling water pollution.

Relevance to Hydropower:

Three sections have a direct impact on hydropower development.

Section 401: An applicant for a FERC license must indicate to the state designated agency that the proposed project will comply with state water quality and effluent standards. These standards vary from state to state and each state's effluent limitations need to be checked to determine if the limitations present a problem.

Section 402: The EPA is deciding whether a discharge from a dam is a point source and therefore would require the issuance of a permit. A Federal District Court in South Carolina ruled that a hydroelectric dam may be regarded as a point source under certain circumstances. (South Carolina Wildlife Federation v. Alexander. Cir. No. 76-2167, D.S.C., filed November 16, 1976). EPA has not issued regulations to cover hydropower facilities.

Hydrologic conditions and economics usually determine the type of operation and the manner of reservoir release. Climate, ambient water quality, soil conditions, and operation all influence the quality of release water. EPA is already on record as stating that dams are not point sources because they do not cause an addition of pollutants to the waterway. If a discharge permit is required for hydroelectric dams, more than fifty thousand dams may require a discharge permit.

Section 404: The Army Corps of Engineers issues permits for the discharge of dredging or filling material in navigable waterways. The material must be disposed at sites selected in accordance with guidelines developed by EPA. The Corps will not issue a permit unless a proper site can be found. The Corps may also put restrictions on the amount and timing of dredging to minimize negative environmental effects such as those on spawning areas.

EPA published consolidated permit regulations on May 5, 1980, (40 CFR 122, 123, and 124) setting uniform procedures to obtain permits under several Agency laws including Sections 402 and 404 of the Clean Water Act. The consolidated permit program is an attempt by the Agency to make it easier for any applicant to apply for EPA permits.

Act:

Coastal Zone Management Act (PL 92-583).

Implementing Agencies:

National Oceanic and Atmospheric Administration, state coastal zone commissions.

Action:

Permits required in some states.

Purpose:

The Act calls upon the nation to preserve, protect, develop, and where possible, restore or enhance, the resources of the nation's coastal zones for this and succeeding generations. It encourages the states to protect and manage their coastal lands and provides federal funds for that purpose.

Relevance to Hydropower:

A federal project or federally-licensed project that will be located in the jurisdiction of a coastal zone commission will be subject to the provisions of the plan developed by the commission. Many states have a policy of restricted development on their coastlines. Proponents of a hydropower project would have to demonstrate that it is an appropriate use of the coastal zone.

Act:

Endangered Species Act of 1973, (PL 93-205).

Implementing Agencies:

U.S. Fish and Wildlife Service, National Marine Fisheries Service.

Action:

Review.

Purpose:

The Act is intended to conserve the ecosystems upon which endangered and threatened species depend.

Relevance to Hydropower:

The Secretary of Interior lists species in danger or likely to be in danger of extinction. Once listed, this Act prohibits development of any project if it will affect a significant portion of the critical habitat of an endangered species. The developer must prove to the fish and wildlife protection agencies that no critical habitat is threatened. Federal agencies can deny permits or licenses on the basis that the proposed project threatens the critical habitat of an endangered species.

At present, few projects have been terminated as a result of the Act, but many projects have experienced delays and litigation. It is the only federal legislation with the authority to stop development on a project.

As a result of extensive litigation and delay over the "snail darter" controversy at Tellico Dam site, Tennessee, the Congress amended the Act in 1978. The Amendment provides a procedure for the establishment of review boards for exempting significant projects from the constraints of the Act.

Act:

Energy Security Act of 1980 (PL 96-294).

Implementing Agency:

Federal Energy Regulatory Commission.

Action:

Licensing.

Relevance to Hydropower:

The Energy Security Act continued the efforts to streamline FERC procedures for licensing power facilities at existing sites. In the Act, FERC was asked to develop regulations to exempt hydropower facilities with capacity less than 5 MW from some licensing requirements. FERC is to decide what classes or categories may be exempt from licensing requirements. (The Commission has already published proposed regulations for exempting facilities on a case by case basis (FERC Docket No. RM-80-65, August 27, 1980), and on a limited categorical exemption (FERC Docket No. RM81-7, December, 1980). In these regulations, FERC proposes to process requests for exemptions within four months of acceptance. A key element of the law and the implementing regulations is that fish and wildlife protection be ensured. As of June 30, 1980, there were 379 preliminary permits, preliminary permits in effect, and license applications and over 50 percent were under 5 MW and may be eligible for an exemption.

Act:

Federal Power Act (16 U.S.C.. 791a et seq.).

Implementing Agency:

Federal Energy Regulatory Commission.

Action:

License for non-federal projects.

Purpose:

Regulate non-federal hydropower affecting the interstate supply of electricity.

Relevance to Hydropower:

Although the Federal Power Act (FPA) is not an environmental statute per se, there are two provisions of the Act that require environmental considerations as part of the licensing process. Section 811 mandates the FERC to require the construction, maintenance and operation of fishways prescribed by the U.S. Fish & Wildlife Service and the National Marine Fisheries Service. It is not generally known what the overall national requirements will be for fish passage facilities in an expanded small-scale hydropower program, but fish passage is now a common requirement for hydro projects. Section 4(e) of the Federal Power Act provides that FERC cannot issue a license affecting the navigable capacity of a waterway without the approval of the Chief of the Army Corps of Engineers and the Secretary of the Army (see River and Harbor Act of 1899 in this appendix).

FERC requires considerable documentation of recreational opportunities at the hydropower facility. In many cases, access and recreational facilities must be provided to the public.

For the purposes of NEPA, FERC must determine the environmental impacts of taking the federal action to issue a permit. FERC has developed a process whereby the license applicant handles most of the consultation and compliance activities as part of its preparation of an environmental report.

The FERC licensing process under the Federal Power Act is the mechanism driving compliance with all the other environmental legislation discussed in this appendix.

Act:

The Fish & Wildlife Coordination Act (PL 85-624).

Implementing Agencies:

U.S. Fish & Wildlife Service, National Marine Fisheries Service, state fish and wildlife agencies.

Action:

Review.

Purpose:

The purpose of the Act is to ensure that fish and wildlife conservation receive equal consideration with other features of water resource development programs.

Relevance to Hydropower:

This law mandates that all federal agencies consider fish and wildlife impacts for their actions. It authorizes fish and wildlife protection agencies to review license applications and recommend mitigation.

The major effect on hydropower under the Act is that fish ladders or fish elevators are frequently required to be constructed to facilitate the passage of anadromous fish. The Fish and Wildlife Service could recommend the addition of fish passage facilities or funding the construction of fish hatcheries to mitigate negative environmental impacts. These facilities can be extremely costly and can alter project feasibility.

The Act also has provisions for mitigating impacts on wildlife habitat although this occurs relatively infrequently. Mitigation measures often include buying and designating parkland or wetlands for that purpose.

The FWCA was passed in 1936 and amended extensively in 1958 and 1965. Regulations to implement the Act had never been issued until proposed regulations were published in May 1979 providing for early consultation between the construction agencies and the wildlife agencies for equal consideration of wildlife resources and construction agency objectives.

After an extensive comment period, the Departments of Interior and Commerce decided to prepare a ful EIS on the federal action. Preparation of the EIS will delay final regulations approximately one year, although federal agencies are proceeding with draft regulations.

Policy:

Floodplain Management, May 24, 1977, Executive Order 11988.

Authority:

National Environmental Policy Act, the National Flood Insurance Act of 1968, and the Flood Disaster Protection Act of 1973.

Implementing Agencies:

All federal agencies; Council on Environmental Quality.

Action:

Review.

Purpose:

Each agency is to take the leadership to reduce the risk of flood damage, minimize the impact of floods, and to restore and preserve the natural and beneficial values of floodplains.

Effect on Hydropower:

If a project has to be located in a floodplain, the Agency must consider alternatives to adverse effects and incompatible development. Each agency must develop procedures to carry out the order and the Council on Environmental Quality will evaluate federal agency compliance with the order and report periodically on this to the President. The Corps of Engineers was one of the first agencies to incorporate the order into its planning procedures.

Act:

The National Environmental Policy (PL 91-190).

Implementing Agencies:

Council on Environmental Quality, Environmental Protection Agency, all federal agencies.

Action:

Review.

Purpose:

Makes protection and enhancement of environmental quality the responsibility of all federal agencies. The Act is largely implemented through environmental impact statements.

Relevance to Hydropower:

There are many actions taken by agencies involved in hydropower that are subject to NEPA -- the FERC license, the DOE loans, REA's construction loan, and the Corps construction of a hydropower project. For federal hydropower projects, an EIS will probably be required for each project. FERC generally will be the lead agency for non-federal projects and decide whether to prepare an EIS.

Each applicant for a FERC license on a project larger than 1.5 MW, except conduit facilities, prepares a comprehensive environmental report. The report normally includes information about how the project will comply with the other environmental statutes, as well as NEPA. The FERC uses the report as a background information in the preparation of its EIS on the project. For a Corps project, the EIS is prepared during the planning period of a project and is a major vehicle to solicit public and other agency comment on a proposed project.

<u>Act</u>:

National Historic Preservation Act of 1966 (PL 89-665) and Executive Order 11593, "Protection and Enhancement of the Cultural Environment".

<u>Implementing Agencies</u>:

Advisory Council on Historic Preservation, Heritage Conservation and Recreation Service, State Historic Preservation Officer.

<u>Action</u>:

Review, designation.

Purpose:

The Act is intended to preserve historical and cultural foundations of the nation as a living part of our community life and development in order to give a sense of orientation to the American people. The Act created the National Register of Historic Sites. The Register is a powerful federal instrument to carry out protection of historic sites.

Relevance to Hydropower:

Regulations carrying out the Act require a prospective developer to determine if the proposed project is on or near a listed site. If not, he must detemine whether there is any site on or near his development that is "eligible for listing". Determining whether a project is eligible may become very expensive as professional advice is usually required. In addition, FERC requires applicants for major projects to prepare an exhibit to satisfy this requirement.

Once a project is determined to be listed or eligible for listing, a formal negotiation process is required with the Advisory Council and the State Historic Preservation Officer. If the proposed project is determined to have adverse effect, the parties attempt to agree upon mitigative or avoidance measures. Delays could extend through the licensing or the planning process if no agreement is reached. if agreement is reached on mitigating measures, a memo of understanding is signed by the parties and the project is free to move forward.

The Tax Reform Act of 1976 provides incentives for the rehabilitation of historic sites. If the redevelopment or retrofitting can be done while preserving the historical integrity of the structure, the tax benefits could be advantageous.

Act:

National Trails System Act (PL 90-543).

Implementing Agencies:

Heritage Conservation and Recreation Service, U.S. Forest Service.

Action:

Designation, review.

Purpose:

The Act provides for development and management of a Scenic Trails System comprised of trails with historical significance. At present, two trails have been designated and are being managed -- the Appalachian Trail in the east and the Pacific Crest Trail in the west.

Relevance to Hydropower:

Hydropower power projects can be built near the trail if they do not "substantially interfere with the nature and purposes of the Trail". Hydro development has not yet been affected by this legislation.

Policy:

National Wetlands Policy, Executive Order 11990.

Authority:

National Environmental Policy Act of 1969.

Implementing Agencies:

All federal agencies.

Action:

Review.

Purpose:

Each federal agency must review its actions to minimize the destruction loss, or degradation of wetlands and to preserve and enhance their beneficial values.

Relevance to Hydropower:

Section 150 of the Water Resources Development Act of 1976 authorizes the Corps to plan and establish wetlands as part of water resource development projects. For Corps projects, consideration of wetlands is part of the planning process for a water resource project within the Principles and Standards.

The definition of wetlands in the order is not very clear and this hinders uniform application of the policy. The Corps and federal agencies have developed general policies and procedures to carry out the order.

Policy:

Principles & Standards

Authority:

Water Resources Planning Act of 1965 (PL 89-80, amended by 94-112).

Implementing Agency:

Water Resources Council.

Action:

Review.

Purpose:

The Principles & Standards (P&S) is a federal policy that is used for directing improvement in the development of water resource projects through contributions to the objectives of national economic development (NED) and environmental quality (EQ). The two main objctives must be displayed in four separate accounts that provide the beneficial and adverse effects on regional development, social well-being, water conservation and non-structural alternatives. The Water Resource Council publishes the P&S and sees to it that the designated federal agencies carry them out.

Relevance to Hydropower:

Federal hydropower construction agencies, such as the Corps and Water and Power Resources Service are mandated to use the P&S. The process is similar to the new EIS process in that it assists the agency to identify alternative courses of action and provides information to improve the development agency decision-making process. In addition to requiring the agencies to array information by the system of accounts, the agencies must incorporate the other environmental requirements, mentioned in this section, into the discussion of the main objectives. As a result of NEPA and the P&S, the Corps evaluates environmental effects, investigates alternatives and postures mitigation measures.

In Chapter VII, we discussed more fully how a Corps project is developed under the Principles & Standards.

Act:

Public Utility Regulatory Policies Act (PL 95-617).

Implementing Agency:

Federal Energy Regulatory Commission.

Action:

Licensing non-federal hydropower projects.

Purpose:

The Act encourages conservation of electric energy, improvement of wholesale distribution of electric energy, conservation of natural gas, and creates a program for expeditious development of hydroelectric potential.

Relevance to Hydropower:

The Act exempts hydropower facilities with less than 30 MW capacity from certain requirements of the Federal Power Act. In an important provision to help create a market for power developed at small dam sites, the law requires utilities to purchase power at a fixed price (avoided cost) from hydro facilities with less than 80 MW capacity. To carry this out, state public utility commissions are required to develop implementation procedures. The Act gives authority to FERC to streamline the licensing procedures for hydropower facilities up to 15 MW located at existing sites. However, environmental safeguards for fish and wildlife are not reduced and EPA and CEQ are provided an opportunity to review the environmental effects of a project before the issuance of a license. Since 1978, FERC has reduced application requirements for conduits and for projects at existing sites, and particularly for facilities with capacities of 1.5 MW or less.

The Act also authorized funding to the Department of Energy for feasibility studies, demonstration projects, and a construction loan program (for which money has not been appropriated). In addition, the passage of PURPA signaled a commitment by the Congress to promote the development of small-scale, non-federal hydropower.

Act:

Resource Conservation and Recovery Act (PL 94-580).

Implementing Agencies:

Environmental Protection Agency, designated state hazardous waste agencies.

Action:

Permit, designation.

Purpose:

The Act authorizes EPA to control hazardous wastes from the point of generation to the point of final disposal.

Relevance to Hydropower:

The Act requires EPA or a designated state agency to issue a permit for the handling and disposal of dredge spoils that are classified as hazardous wastes. EPA published final regulations in May, 1980, and they have been met with significant controversy. The disposal can only take place at Class I disposal sites which are maintained by public or private entities to meet strict EPA standards.

The individual performing the dredging must decide if the dredge spoils meet the criteria for hazardous waste. If so, a permit must be obtained and a "cradle to grave" reporting procedure followed. Few Class I disposal sites are available and disposal costs in such sites are very expensive. Permits issued under the Act are a part of the consolidated permit process (see Clean Water Act above).

Act:

River and Harbor Act of 1899.

Implementing Agency:

Army Corps of Engineers.

Action:

Permit.

Purpose:

The purpose of the Act is to preserve and protect navigable waterways by prohibiting the construction, alteration or modification of the navigable waterways of the United States without the permission of the Corps, the Secretary of the Army and the Congress.

Relevance to Hydropower:

The Act requires the Corps to issue a permit for construction or dredging in a public waterway. The Act also gives the Corps responsibility for controlling the construction of any obstacles including dams, in navigable waterways. For non-federal projects, the permit issuance provisions of the Act are incorporated by Section 4(e) of the Federal Power Act which authorizes the Corps to review any FERC license before it is issued. The Corps undertakes the review in lieu of issuing a permit. As a result of NEPA, the Corps must also evaluate environmental effects, investigate alternatives, and posture mitigation measures as part of its Section 10 responsibilities.

Act:

Wild and Scenic Rivers Act (PL 90-542).

Implementing Agencies:

Departments of the Interior and Agriculture, Heritage Conservation and Research Service, state environmental protection and recreation agencies.

Action:

Designation.

Purpose:

The intent of the statute is to preserve and protect, in their scenic and free-flowing condition certain rivers for the benefit of this and future generations.

Relevance to Hydropower:

The program began in 1968 with the designation of eight rivers and the recommendations for studying 27 others. The law forbids FERC from licensing facilities that directly affect designated rivers and those under study have already been excluded as potential hydro sites in the Corps National Hydropower Study.

As noted in the GAO study (1980) on renewed interest in hydropower, the 28 rivers already designated as wild and scenic preclude the development of 12,750 MW of hydroelectric power. Fifty-nine river segments are currently under study and FERC estimates they would preclude the development of 9500 MW of capacity. Once a river is designated, a dam cannot be built on the waterway.

An additional barrier to potential development is that many states have established their own state wild and scenic rivers acts. As of January 1, 1978, GAO also noted that approximately 4845 miles of river in nineteen states had been designated as wild and scenic.

Act:

The Wilderness Act (PL 88-577).

Implementing Agencies:

U.S. Forest Service, National Park Service.

Action:

Designation, review.

Purpose:

The purpose of the Act is to protect and manage undeveloped federal land to preserve its wilderness character by establishing the National Wilderness Preservation System.

Relevance to Hydropower:

The law authorizes the Department of Interior and Agriculture to establish wilderness areas. Once designated, the use of a wilderness area is limited to recreation and conservation. Hydropower projects may be constructed and operated in wilderness areas if the President specifically finds that such a use ". . . will better serve the interests of the United States and the people thereof than will its denial."

Environmental organizations are very opposed to any kind of construction affecting wilderness lands, and any such construction proposed would no doubt face lengthy litigation.

APPENDIX H

METHODOLOGY FOR CUMULATIVE IMPACTS

1. The Problem of Assessing Cumulative Impacts

The environmental impacts of a hydropower facility are fairly well known and relatively benign compared with the impacts of thermoelectric power plants. Coal-fired power plants generate significant amounts of air pollution that are potentially damaging to human health, and require excavation of coal that can dramatically disrupt the landscape and severely pollute streams. Nuclear power plants create serious safety and waste disposal problems. Although hydropower plants impact fish, wildlife and land resources, they do not generate air pollution nor do they cause significant water quality problems.

Some would posture that the impacts from hydropower development are preferable to those from other sources of electrical generation. Such reasoning leads one to the conclusion that development of all potential hydropower resources is the environmentally acceptable solution to our nation's energy goals. This seemingly logical supposition is false because it fails to recognize the importance of cumulative impacts.

Development of hydropower projects incrementally destroys a variety of natural and social resources. The combined effect or cumulative impact of full development of a river basin may completely eliminate a particular resource such as anadromous fish, or species of wildlife that depend on a riverine environment. These impacts are significant and possibly worse than the cumulative impacts of other forms of electrical generation.

Few research studies have addressed the problem of cumulative impacts of hydropower, although the New England region is in the forefront of activity. The Federal Power Commission (1976) prepared a basin-wide environmental impact statement on electrical power generation within the Connecticut River Basin focusing on cumulative impacts. Since then the New England River Basin Commission (1979) reviewed possible techniques for assessing cumulative impacts and is currently testing models, in cooperation with the U.S. Fish and Wildlife Service (1979), to assess the trade-offs between power production and protection of fish (personal communication, Bill Knapp, August 7, 1980). In the Pacific Northwest, the Bonneville Power Administration is studying methods to manage their system to protect fish and wildlife. Except for these few examples, however, hydropower impact assessment throughout the country emphasizes individual project impacts rather than the cumulative impacts of several projects.

A thorough assessment of the cumulative impacts of hydropower development in each river basin in the United States is beyond the scope of the present study. However, an indication of the relative levels of impact is feasible and can be a useful tool for national hydropower planning. Such indicators or indices of cumulative impact need to be both relatively easy to apply throughout the country and representative of many different types of impacts. We have developed several possible indices that are reviewed briefly in this chapter. Additional indices could be developed that more accurately estimate levels of impact. However, complex indicators are likely to be limited to assessing specific types of problems within specific regions. We have attempted to identify measures that can be universally applied to every region and every type of impact. The indices we suggest are not independent variables and each one will increase with an increase in hydropower development. However, the rate of change will vary depending on the type of development and the physical characteristics of the watershed. Thus, each index will be sensitive to a particular group of cumulative impacts. The appropriate index or indices to assess cumulative impacts should balance, whereby different river basins with totally different problems can be compared on the same basis. This comparison can guide policy-makers in decisions to target specific river basins for additional development.

2. Potential Indices

a. Developed Hydropower Potential

The first index we propose is a measure of the developed hydropower potential in the river basin--or stated another way, the percentage of the theoretically available resource that has been captured. This measure incorporates the concept of potential energy of a river basin as outlined by

Arvanitidis and Rosing (1970) and allows calculation of marginal loss of hydropower potential as a result of proposed development. This index is described as follows:

$$D = \frac{E}{P}$$

where

D = developed hydropower potential in percent

E = existing hydropower development in kilowatts

P = theoretical hydropower potential of a river in kilowatts

The theoretical hydropower potential of a river (P) is calculated using the following standard equation:

$$P = \frac{Qhe}{11.8}$$

where

P = power production in kilowatts

Q = flow through turbine in cubic feet per second

h = hydraulic head on the turbine in feet

e = efficiency of turbine

11.8 = a constant that accounts for the weight of the water, (62.5 lbs/ft^3) and the rate that work is performed (1 kilowatt = 737 ft-lb/sec)

The maximum available "Q" is the average streamflow at the mouth of the river. The maximum potential "h" is approximated by the fall of the river. The maximum possible turbine efficiency, "e", is 100 percent.

Using these few simple variables, the maximum potential hydropower capacity of a river basin can be estimated. This value will greatly exceed the technically practical and economically feasible hydropower potential of a river basin. For example, using this method Shuster (1978) found that the

Connecticut River Basin, which is the most heavily developed basin for hydropower in New England, was only developed to 14 percent of its potential. The Columbia River Basin, which is the most heavily developed basin for hydropower in the country, is developed to 55 percent of its potential. This technique should not be used to estimate the realistic potential for additional hydropower development but can be used to easily (albeit crudely) compare the relative level of hydropower development in two dissimilar river basins.

b. Control of Streamflow

Alteration of the natural streamflow regime is a significant cumulative impact resulting from development of water resources development within a river basin. Alteration of streamflow can disrupt the migratory patterns of fish, dewater wetlands and other wildlife and game habitat, scour streambeds and erode banks, and greatly reduce the potential for white water recreation. Impacts result primarily from a change in the natural variation of streamflow and from the replacement of a riverine environment with a lake environment. Generally, hydropower facilities used for peaking power will cause a larger variation in daily streamflow and smaller variation in seasonal streamflow than would be experienced naturally.

We propose this second index as a measure of the degree of alteration of natural streamflow that results from development. This index does not recognize the distinction between reservoirs designated for hydropower and those designated for other purposes. However, that distinction may only be important when considering retrofit. Control of streamflow is estimated using the following simple formula:

$$\text{Control of Streamflow(\%)} = \frac{\text{Total Storage of Impounded Water (acre-feet)}}{\text{Average Annual Streamflow (acre-feet)}}$$

Estimates of control of streamflow for the major water resource regions of the United States are given in Table H-1. Relatively dry regions of the

Table H-1

ESTIMATES OF CONTROL OF STREAMFLOW FOR MAJOR RIVER BASINS

Major River Basins	Average Annual Streamflow[1] (10^6 ac-ft)	Storage[2] (10^6 ac-ft)	Control of Streamflow (Storage/ Streamflow)
New England	87.604	12.612	0.144
Mid-Atlantic	88.736	119.230	1.344
S. Atlantic-Gulf	255.497	219.277	0.858
Great Lakes	81.475	210.139	2.579
Ohio 199.458	483.519	2.424	
Tennessee	45.718	23.712	0.518
Upper Mississippi	135.586	110.672	0.816
Lower Mississippi	485.198	20.191	0.042
Souris-Red-Rainy	6.734	7.558	1.222
Missouri	49.416	115.456	2.336
Arkansas-White-Red	70.146	69.867	0.996
Texas-Gulf	25.680	55.422	1.749
Rio Grande	2.563	14.411	10.455
Upper Colorado	11.206	12.366	1.103
Lower Colorado	1.737	72.111	41.518
Great Basin	2.871	4.200	0.356
Pacific Northwest	239.802	68.007	0.238
California	53.086	146.163	2.704
Alaska	1014.098	0.870	0.001
Hawaii	7.560	0.053	0.007

Notes: 1. From Seinwill and Davenport, 1979. Original Source U.S. Water Resources Council, 1978.

2. McDonald, 1977.

3. U.S. Fish and Wildlife Services estimates for optimal fish and wildlife habitat conditions cited in Seinwill and Davenport, 1979.

country (Lower Colorado and Rio Grande) with low annual streamflow have the highest values. Cumulative impacts in these regions are water quality related. Salinity levels at Imperial Dam on the Lower Colorado River average 823 mg/l in 1976 compared to the EPA maximum standard for drinking water of 500 mg/l (Comptroller General, 1979). The primary cause of increased salinity is consumptive use of stored water--not a direct effect of hydropower development. However, very few reservoirs are developed with hydropower as a single purpose. In fact, hydropower generation is often a secondary use. The economic feasibility of many large water projects can only be justified with multiple uses. As a result, the impacts of hydropower development should not be isolated from other reservoir-related impacts.

c. Length of Impoundment

Extensive hydropower development changes a river into a series of pools which essentially replaces a river environment with a lake environment. Impoundments trap sediments and nutrients, change streamflow, alter water temperatures and inundate adjacent land. Overall, the creation of impounded water is responsible for many impacts. The degree of impoundment of a river can be simply calculated as follows:

$$\text{Degree of Impoundment (\%)} = \frac{\text{Total Length of Impounded Water (miles)}}{\text{Total Length of River (miles)}}$$

A river basin that is fully developed has a ratio of one. For example, the Connecticut River is 44 percent impounded and the Columbia is 74 percent impounded.

Although a single impoundment ratio can be used as an index of cumulative impact, the change in this ratio along different reaches of the river may also be important. Figure H.1 showed how this ratio changes along the Columbia River from the mouth to Chief Joseph Dam before and after the construction of John Day Dam--the last constructed along this stretch of river. With the addition of John Day in 1968, the Columbia became a series of continuous

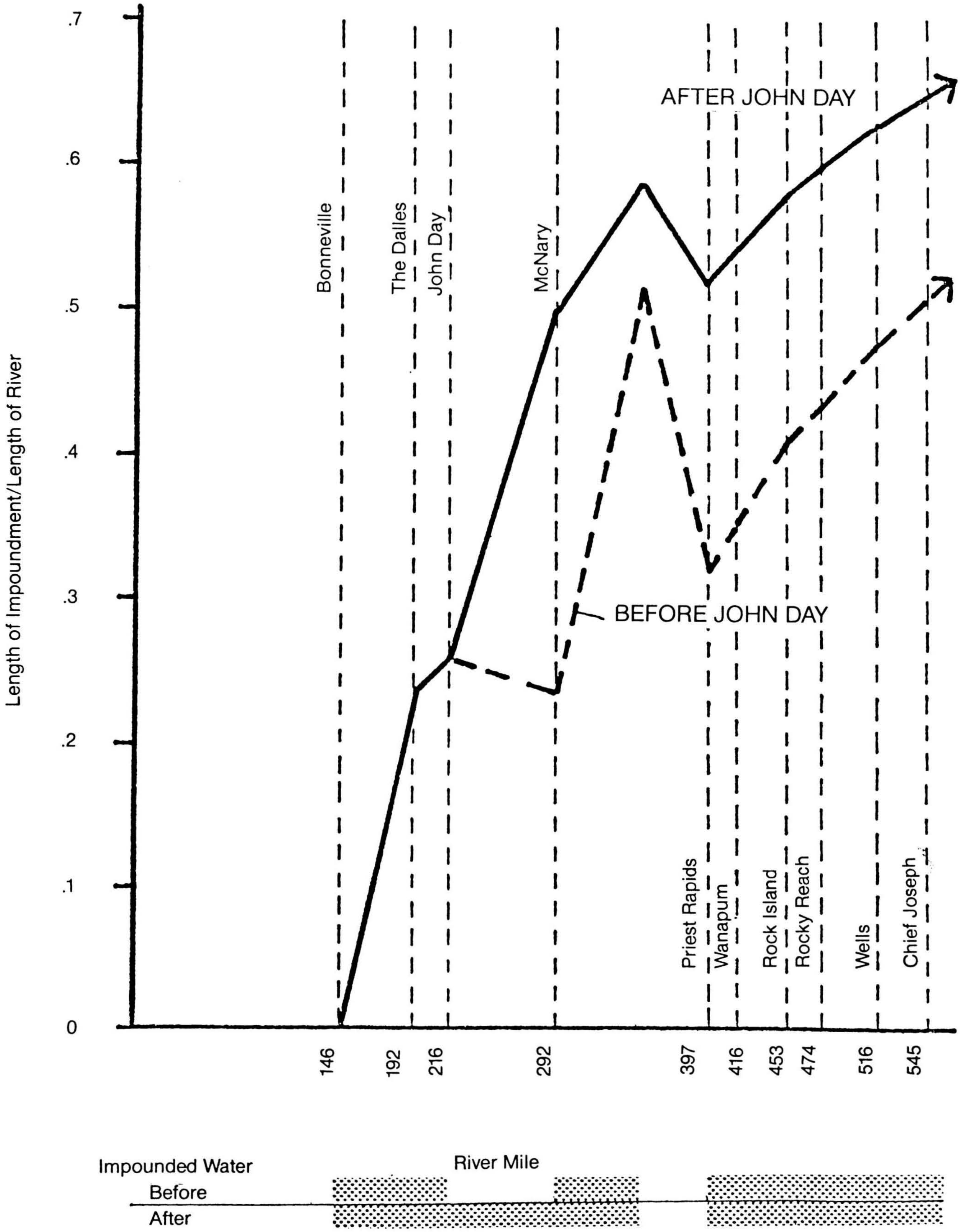


Figure H.1 CUMULATIVE RATIO OF IMPOUNDED WATER TO LENGTH OF RIVER ALONG THE COLUMBIA impounded pools for more than two hundred miles followed by a 50 mile stretch of unimpounded water and then another 150 miles of continuous pools of impounded water to Chief Joseph Dam. At that time, the anadramous fish population began to drop dramatically. The change in this ratio could conceivably have been used to indicate the potential for serious problems before the John Day Dam was constructed.

d. Land Inundated

The creation of a reservoir can potentially inundate wildlife habitat, agricultural land, timber, archeological sites and uran areas. Although the percentage of a river basin affected is generally small, this ratio may provide an indication of the terrain in which the river basin is located. The ratio is calculated as follows:

$$\text{Land Inundated (\%)} = \frac{\text{Cumulative Surface Area of Reservoirs (square miles)}}{\text{Area of Drainage Basin (square miles)}}$$

A river with a gentle terrain will have a higher ratio than a river with the same general drainage basin size but a steeper terrain. In addition, rivers with gentle terrains often have an established floodplain with associated wetlands and riparian vegetation. This area is excellent wildlife habitat and frequently prime agricultural land. Therefore, this index may provide a surrogate for measuring these primary impacts.

e. Additional Indices

Although the preceding indices are adequate for the purposes of this study, we have cursorily investigated several additional indices to assess specific types of impacts. They are discussed below. Unfortunately, these indices often require more data and analysis and may not be generally applicable to all regions and impacts. However, detailed indices could be valuable tools for planning within a specific river basin. We suggest that the feasibility for using these or any additional indices be investigated during the next phase of the research.

(1) Historical Alteration of Streamflow

The second indicator that measures control of streamflow (Section 2b) could be improved by incorporating historical data to more accurately portray a shift in the flow regime of a stream. As previously mentioned, one would expect intensive hydropower or water resources development to amplify a stream's daily hydrograph and to dampen its seasonal hydrograph. This can be measured by computing the standard deviations for hourly and monthly streamflow averages. The change before and after development would provide an excellent index of the alteration of streamflow from hydropower.

(2) Universal Streamflow Standards

Universal streamflow standards offer a method of assessing the ability of a river to withstand further fluctuations in streamflow. The Connecticut River Basin Coordinating Committee recommends that main river dams in that river basin be required to release at least 0.20 cubic feet per second for each square mile of drainage area upstream of the dam. The Technical Committee for Fisheries Management of the Connecticut River Basin initially recommended a standard of 0.25 (Shuster, 1978). Recently the U.S. Fish and Wildlife Services has been recommending a standard of 0.5 (Knapp, personal communication). This type of standard can be applied throughout a watershed and recognizes the natural relationship between the watershed and streamflow. As indicated in Figure H.2, historical data from periods of low streamflow can be used to assess how reasonable a particular standard might be and to establish operating procedures that will minimize deviation. In the case of the Connecticut River, future droughts will require implementation of procedures that maintain flow near the required level.

(3) Recreation

The creation of reservoirs for hydropower generation are commonly also used for recreation. Increased recreational use in turn creates demand for housing development, increased transportation, and other services that generates a second series of impacts. The magnitude of these impacts can be inferred from the predominance of flat-water recreational use. This can be measured by taking the ratio of flatwater visitor-days to free-flowing river visitor days. We recognize that these data may only be available for rivers or reservoirs located on state or federally owned land. However, this simple ratio would provide an excellent surrogate for measuring both growth-inducing impacts of development and the need for additional flat-water recreation in the basin.

3. Procedure for Evaluating Cumulative Impacts

a. Overview

If the indices were verified with case studies, they could be used to assess regional difference. A procedure for assessing the regional cumulative impacts of hydropower is outlined in Figure H.3. The sections that follow do not provide detailed methods for estimating or calculating the required data for each step in the procedure. Rather, they provide a discussion of the process, a description of the requirements, and in some cases, a warning of potential pitfalls.

The first step in the process is to estimate the developed hydropower potential of the river basins as outlined above. Because regional study area boundaries often do not conform to river basin boundaries, in some cases, the hydropower potential will be estimated based on a proportion of the river basin area within the region. The existing level of development can be determined from the Corps' inventory and compared to the theoretical potential to estimate the relative level of development.

The second step identifies the resources being lost from hydropower development within the region. Impacted resources can be determined from the questionnaires, workshops and representative documents used to conduct the generic regional environmental assessment.

The third and fourth steps in the process classify the type of relationship that exists between hydropower development and the loss of resources. The extent of the particular resource throughout the region and its dependence on the river will indicate the maximum loss of the resource if

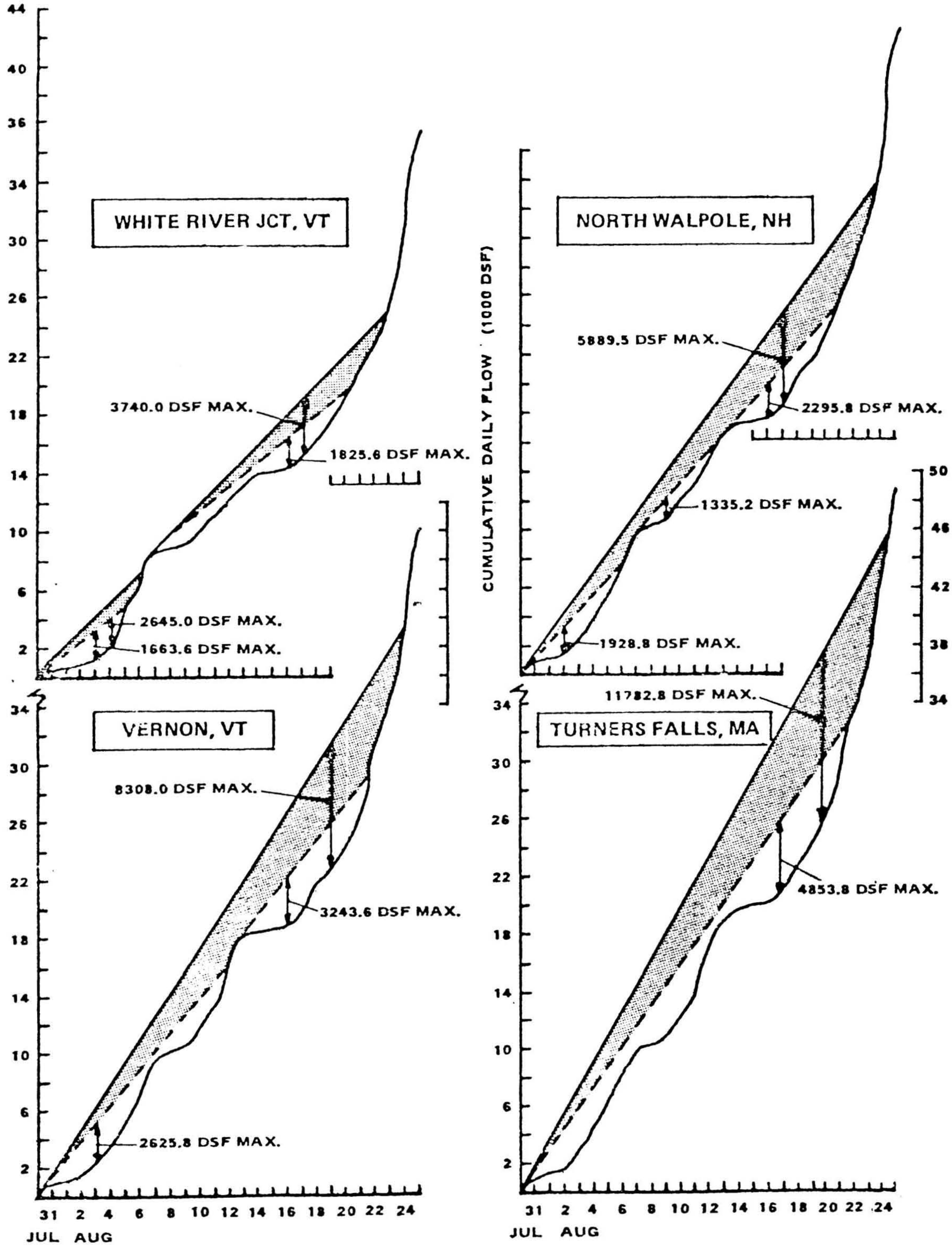


Figure H.2 CONNECTICUT RIVER STREAMFLOW DURING INTENSE DROUGHT OF JULY-AUGUST 1964 SHOWING DEVIATION FROM MINIMUM FLOW STANDARDS

Source: U.S. Geological Survey Gauging Station Records
and Federal Power Commission, 1976

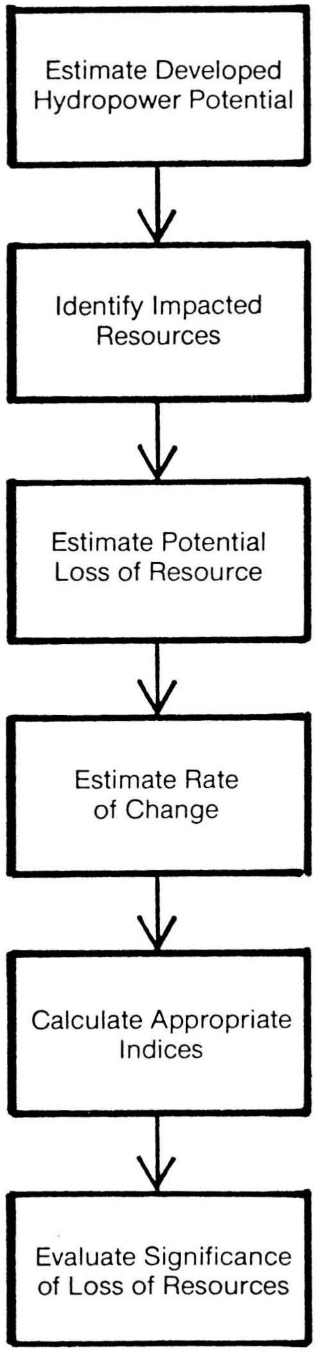


Figure H.3 MAJOR STEPS IN PROCEDURE FOR EVALUATING CUMULATIVE IMPACTS the river basin was fully developed. Many types of resources would be completely eliminated under this extreme condition. Others such as timber and urban land use would be only partially lost. The expected rate of change of the resource with initial and then increasing levels of hydropower development should also be estimated.

The next step is to select the appropriate indices for that region. Case study results can be used to match indices to regions with similar impacted resources. For example, an index appropriate for the Pacific Northwest, where loss of anadromous fish population is a serious cumulative impact, may be an appropriate index for northern California. Conversely, it may not be appropriate for west Texas, where loss of riparian vegetation is a significant concern.

In the final step, a value is placed on the significance of the resource by considering its sphere of influence and the cost of mitigation to protect this resource. The value of the resource is partially dependent on its uniqueness. The loss of a resource that is common throughout the nation--for example, Douglas Fir forests--is obviously of less importance than the loss of a resource that is only found in a few locations--a coastal redwood forest, for example.

The completion of this evaluation procedure for each region, gives a picture of the impacted resources and the status of development in each basin. In addition, the indices can be used to compare the relative level of existing impacts and to identify which of these regions might be approaching its carrying capacity or exceeding it.

b. Estimating the Potential Loss of Resources

Many types of resources can be lost from hydropower development. White water recreation, anadromous and cold water fishing, wildlife, prime agricultural land, timber, historic sites, archeological sites, scenic areas, transportation routes and building structures are resources commonly impacted by hydropower development.

INDEX	RATIO	RESOURCES: Water Quality	Archaeology	Water Supply	Scenic	Historic/Cultural	Urban Land	Timber	Agricultural Land	Game	Wildlife	Anadromous Fish	White Water Recreation
Control of Streamflow	Total Storage/Annual Flow	●		●								●	○
Impoundment	Impoundment Water/Length of River				●					○	○	●	●
Land Inundated	Reservoir Surface Area/Watershed Area		●			●	●	●	●	●	●		

Key: ● primary relationship
○ secondary relationship

Figure H.4 RELATIONSHIP BETWEEN INDICES AND IMPACTED RESOURCES

RESOURCE	AFFECTED ENVIRONMENT				RESOURCE ZONE OF INFLUENCE			
	Instream	Riparian	Floodplain	Watershed	Local	State	Regional	National
White Water	●						●	○
Anadromous Fishery	●						●	○
Wildlife Species		●	○	○	○	●		
Game Species		●	○	○	○	●		
Agricultural Land			●		●			
Timber				●	●			
Urban Land			●	○	●			
Historical/Cultural			●	○		●		
Scenic				●	●	○	○	○
Water Supply	○			●		●	○	
Archaeological			●	○		●	○	○
Water Quality	○			●				

Key: ● primary
○ secondary

Figure H.5 CLASSIFICATION OF RESOURCES IMPACTED BY HYDROPOWER DEVELOPMENT

Although many different measures could be used to assess each of these types of cumulative impacts, a few can be selected that reliably represent broad groupings of impacts. As shown in Figure H.4, the indices previously discussed are indicators of the stress placed on a specific set of resources.

Hydropower development impacts those resources that are vulnerable to changes in the hydrologic regime. The degree of vulnerability indicates the level of impact to be expected. Resources, such as fisheries, are totally dependent on the flow of the river itself--these are most directly impacted by development. Other resources, such as wildlife, are dependent on the vegetation along the edge of the river as well as the associated woodlands in the watershed. These resources are less directly impacted.

The associated environments (or type of habitat) affected by hydropower development can be categorized as follows: instream, riparian, floodplain, and watershed. The relationship between the impacted resource and the affected environment is important in estimating the expected rate of change. Simply, the resources directly dependent on the instream environment will suffer the greatest losses; those dependent on the watershed as a whole will suffer the fewest. These relationships are presented in Figure H.5. (The zone of influence will be discussed in Section C.)

The rate of change of a resource with respect to incremental hydropower development is important in determining the potential loss from additional development. This marginal change will occur in one of four basic ways (see Figure H.6): linear, asymptopic, exponential, or variable.

The differences in the rate of change will have a significant influence on the response of the resource to the incremental development. A linear relationship (Figure H.6A) means that the incremental impact of an additional unit of hydropower development is always the same (i.e., the marginal impact is constant).

The loss of riparian vegetation, for example, may be linearly related to the level of hydropower development. The relationship can also be asymtopic (Figure H.6B). In this case, the initial development of hydropower greatly destroys the resource and any incremental development will have little effect. The wilderness attribute of a river basin is one resource that may be asymtopically related to hydropower development. An anadromous fishery may also be asymtopically related if the initial dam is constructed near the mouth of the river without fish passage facilities. Other resources may have an exponential relationship with hydropower development such that the initial impacts are relatively small but the marginal effect of additions have progressively larger impacts (Figure H.6C). Changes in flow regime, for example, appear to increase exponentially with hydropower development. Finally the relationship between hydropower development and loss of the resource may be irregular (Figure H.6D). Thresholds of impact or unpredictable placement of the resource such as archeological resources could result in a variable relationship.

The importance of these relationships becomes clear with a few examples. As mentioned, a resource that has an asymtopic relationship with hydropower development will show little marginal loss with incremental development. Therefore, a policymaker could conceivably decide to develop the river completely on the basis of the expected small marginal loss. Conversely, a resource that is exponentially related to development will show substantial marginal losses with incremental development. In this case, the policymaker may decide that additional development is unwise.

c. Evaluating Significance

The impact of losing a resource is not only dependent on the degree and rate of depletion but also on the value of the resource to society. Monetary prices and individuals' willingness to pay for a resource are commonly used to represent a value of a resource to society. However, practically all of the resources lost from hydropower development are "public goods" in the economic sense--in other words, the value to society is greater than the collective price individuals are willing to pay (see, for example, Pogue and Sgontz). Therefore, alternative techniques must be used to reflect the resource's value to society. The resource's sphere of influence and expenditures to mitigate impacts are two indirect measures of a resource's value.

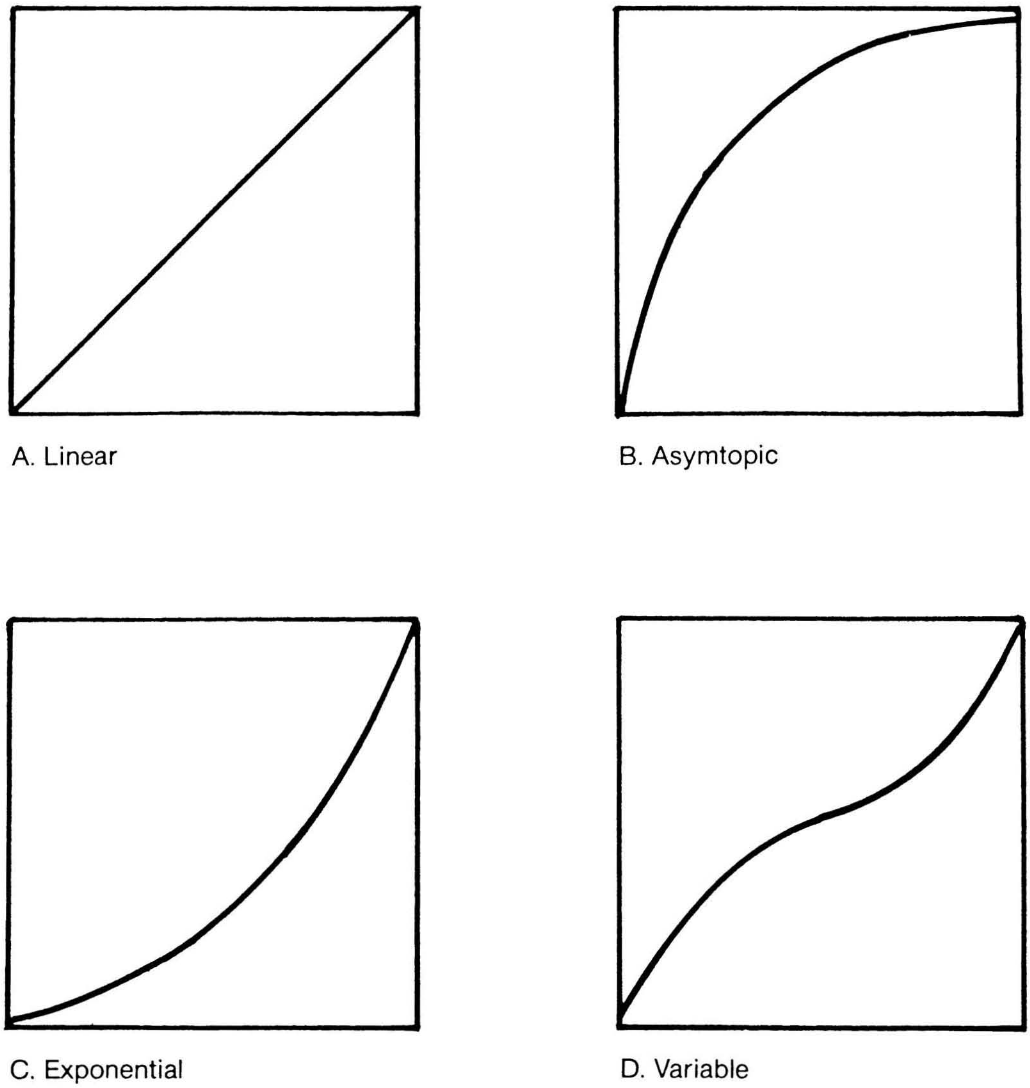


Figure H.6 GENERALIZED ALTERNATIVE RELATIONSHIPS BETWEEN HYDROPOWER DEVELOPMENT AND LOSS OF A RESOURCE

A resource's sphere of influence is the extent of the area in which users or potential users will be affected if the resource is lost. Sphere of influence is analogous to a product's market area. Unique resources have large spheres of influence and are generally more valuable to society than common resources that have small spheres of influence. Clearly, impacted resources with national significance are likely to elicit debate and to require extensive mitigation.

As an aid in identifying the relative value of different resources depleted by hydropower development, four levels of sphere of influence can be established: local, state, regional, and national. Typical classifications for particular types of resources are given in Figure H.5. In some cases, both a primary and secondary sphere of influence is indicated. These classifications are subjective; however, when issues are raised regarding a specific development within a river base, the sphere of influence is readily apparent. For example, agricultural land produces products for a national market but because it is spread throughout major sections of the country, the loss of acreage from hydropower development within a given river basin will not have a significant effect on the national market but could severely affect the local economy.

The resources lost from hydropower development partially depend on measures taken to protect the resource. If the resource is highly valued by society, large amounts of money will be spent to minimize losses from actions taken to create another benefit. Fish ladders and other expensive measures to reduce impact on fish exemplify the value of a fishery to society. Mitigation measures are often undertaken in response to legislative mandates--another indication of the value society places on a resource. Increasing demand for mitigation is a sign that a critical point or threshold is being approached.

Environmental thresholds are levels of impact with extremely high marginal costs--so high that any further impact is not acceptable. Thresholds can be considered purely from a scientific perspective (e.g., the point at which any further reduction of a species population base will prevent the species from successfully reproducing), but most thresholds or critical levels of impact are usually tied to human values about the affected environment.

Through the legislative process, society has defined some environmental thresholds that can limit hydropower development. For example, the Wild and Scenic Rivers Act forbids the Federal Energy Regulatory Commission from issuing a license for a project that would affect a designated river. The Endangered Species Act also prohibits hydropower development if a critical habitat would be adversely affected.

In general, however, absolute limits of acceptable impacts are not clearly stated. Minimum streamflows have the potential to provide limits on operating procedures for hydropower facilities and could preclude new peaking facilities, but they have not been mandated in many regions. Increasing demand and cost for mitigation is perhaps the best indication that the level of hydropower development may be approaching the river basin's carrying capacity. Using demand for and cost of mitigation as a measure of an impending environmental limit assumes that the impacts of hydropower development can be accurately predicted and that adequate mitigation measures are available to effectively reduce impacts to an acceptable level.

Although mitigation costs may not reflect the true environmental costs nor provide assurance that a river basin's carrying capacity is not exceeded, they do provide a relative indication of the significance of the cumulative impacts of hydropower development.

d. A Theoretical Model

The concepts derived in the preceding discussion can be combined to provide a theoretical model for evaluating the cumulative impacts of hydropower development. These relationships are graphically displayed in Figure H.7. If adequate information were available, the historical relationship between the level of hydropower development and the loss of a particular resource could be characterized (Figure H.6A). From this, one could determine the marginal cost of incremental development with respect to that resource.

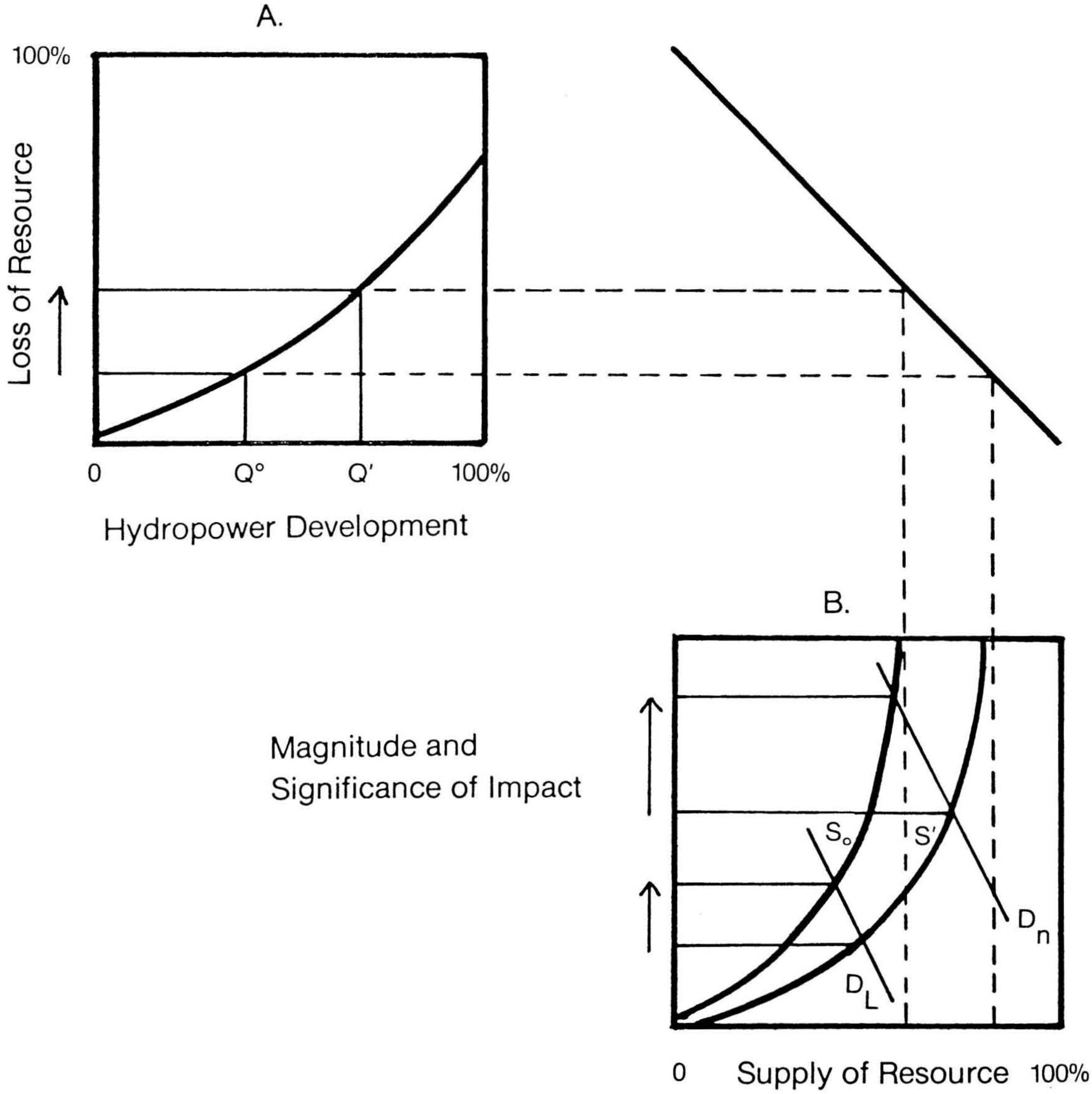


Figure H.7 THEORETICAL RELATIONSHIPS BETWEEN CUMULATIVE HYDROPOWER DEVELOPMENT, LOSS OF IMPACTED RESOURCE AND SIGNIFICANCE OF IMPACT

With incremental development of Q', for example, we would deplete the resource to a level of S'. An additional determination of the value of this resource to society would give us an indication of the significance of the loss (Figure H.6B). A resource with national significance (DN) will cause more ramifications if depleted than one with only local significance (DL). Unfortunately, the information necessary to calculate these relationships is rarely available. Nevertheless, the concept alone is a valuable tool for organizing information and for developing approaches to evaluate cumulative impacts.

APPENDIX I

DESCRIPTION OF REPLACEMENT ENERGY TECHNOLOGIES

COAL

SYSTEM:

- Coal-fired steam electric power plants generate electricity by using steam produced from the heat created during coal combustion, to drive turbine/generator units

COMPONENTS

- Coal
- Coal crushing/conveying system
- Coal pulverizing
- Boiler
- Turbine
- Generator
- Feed Water Treatment
- Air Preheater
- Economizer
- Settling Ponds
- Electrostatic Precipitator
- Cooling Towers

RESOURCES USED:

PLANT CHARACTERISTICS

- 500 MW Plant Capacity
- 55% Plant Factor
- 30 Year Service Life
- 34% Plant Efficiency
- 8.2×10^{12} Btu/Year Energy Production
- 2.93×10^{8} Kwh/Year Energy Production

FUEL	Tons
o Coal	147,000

LAND	Acres
o Plant Site	33
o Waste Disposal Area, Temporary	5.9

COSTS	Dollars
o Construction	N/A
o Operation and Maintenance	N/A

PERSONNEL	Workers/Year
o Construction	N/A
o Operation and Maintenance	9

OIL

SYSTEM:

- Oil-fired steam electric power plants generate electricity by converting the chemical energy of oil into steam, which in turn drives a turbine and generator to produce electricity.

COMPONENTS

- Fuel oil handling, storage and feed system
- Steam Generator
- Steam Turbine
- Generator
- Environmental Control System
- Boiler-fed Water Treatment System
- Condenser
- Water Cooling System
- Waste Water Treatment System
- Ash Removal System
- Sludge Dewatering System
- Solid Waste Disposal System

RESOURCES USED:

PLANT CHARACTERISTICS

- 800 MW Plant Capacity
- 55% Plant Factor
- 35 Year Service Life
- 34% Plant Efficiency
- 13.15×10^{12} Btu/Year Energy Production
- 2.93×10^{8} Kwh/Year Energy Production

FUEL	Barrels
o Residual Oil No. 6	469,500

LAND	Acres
o Plant Area	6-12
o Cooling Towers	1.5
o Incremental Surface Storage	.3 acres/yr

COSTS	Dollars (1978)
o Construction (5 years)	$18.0 million
o Operation and Maintenance	$ .5 million

PERSONNEL	Workers/Year
o Construction	25-60
o Operation and Maintenance	11

NATURAL GAS

SYSTEM:

- Gas-fired steam electric power plants generate electricity by using the steam produced in the boiler, which is created from natural gas combustion.

COMPONENTS

- Water Purification System
- Boiler
- Condenser
- Condenser Cooling Water System
- Steam Turbine
- Generator
- Central Waste Treatment Plant
- Air Preheater
- Economizer

RESOURCES USED:

PLANT CHARACTERISTICS

- 800 MW Plant Capacity
- 55% Plant Factor
- 35 Year Service Life
- 34% Plant Efficiency
- 13.15×10^{12} Btu/Year Energy Production
- 2.93×10^{8} Kwh/Year Energy Production

FUEL	Cubic Feet
o Natural Gas	2.87×10^{9}

LAND	Acres
o Plant Site	6
o Cooling Towers	1.5

COSTS	Dollars (1978)
o Construction	$11.1 million
o Operation and Maintenance	$ .4 million

PERSONNEL	Workers/Year
o Construction (4 years)	40.0
o Operation and Maintenance	8.2

NUCLEAR

SYSTEM:

- o Light Water Reactors consist of two types: pressurized-water reactor which heats water without allowing it to boil and the boiling water reactor.

COMPONENTS

- o Containment Structure
- o Reactor Vessel
- o Fuel Assemblies within Reactor Core
- o Steam Separator
- o Turbine Generator
- o Cooling Water Condensor
- o Liquid Waste System
- o Cooling Towers
- o Spent Fuel Storage
- o Waste Treatment Systems
- o Auxiliary Ventilation Control Systems
- o Engineered Safety Features

RESOURCES USED:

PLANT CHARACTERISTICS

- o 1000 MW Plant Capacity
- o 70% Plant Factor
- o 30 Year Service Life
- o 33% Plant Efficiency
- o 21 x 10^{12} Btu/Year Energy Production
- o 2.93 x 10^{8} Kwh/Year Energy Production

FUEL	Tons
o Uranium (UO_2) fuel elements	1.6

LAND	Acres
o Site	4

COSTS	Dollars
o Construction	\$26.3 million
o Operation and Maintenance	\$ .7 million

PERSONNEL	Workers/Year
o Construction (9 years)	29
o Operation and Maintenance	5.7

SOLAR

SYSTEM:

- A flat panel array consisting of single crystal silicon photo voltaic cells which convert solar energy to electricity. The system employs a reflector to increase performance. Power conditioning complement is designed to be capable of delivering peak array power

COMPONENTS

- Solar Arrays
- Reflecting Surfaces
- Inverters/Converters
- Transformers
- Medium Voltage Cabling

RESOURCES USED:

PLANT CHARACTERISTICS

- 88 MW Plant Capacity
- 30% Plant Factor
- 92% Plant Efficiency
- $.84 \times 10^{12}$ Btu/Year Energy Production
- 2.93×10^{8} Kwh/Year Energy Production

FUEL	Btu
o Incident Solar Radiation	6.79×10^{12}
LAND	**Acres**
o Site	230
COSTS	**Dollars (1976)**
o Construction	$116 million
o Operation and Maintenance	$1.9 million
PERSONNEL	**Workers/Year**
o Construction (Peak)	900
o Operation and Maintenance	10

WIND

SYSTEM:

- Wind energy turns a rotor to produce shaft horsepower. The machine operates at constant speed by varying the pitch of the rotor blades.

COMPONENTS

- Rotor Assembly
- Tower
- Generator
- Energy Storage Subsystem
- Step-Up Gears

RESOURCES USED:

PLANT CHARACTERISTICS

- 1.5 MW Plant Capacity
- 33% Plant Factor
- 30 Year Service Life
- 2.93×10^{8} Kwh/Year Energy Production

FUEL

- Wind

LAND	Acres
o Windmill/Plant Site	50.5

COSTS

N/A

PERSONNEL

N/A

GEOTHERMAL

SYSTEM:

- Steam is collected from a naturally producing field and used to drive a turbine generator. The condensed water is then used for cooling.

COMPONENTS

- Production Wells
- Gathering System
- Steam Distribution System
- Turbine-Generator
- Condensers
- Heat Rejection System
- Gas Ejector System
- Electrical Systems and Controls
- Waste Purification

RESOURCES USED:

PLANT CHARACTERISTICS

- 10 - 135 MW Plant Capacity
- 75% Plant Factor
- Site Dependent Service Life
- 15% Plant Efficiency
- 2.47 x 10^{12} Btu/Year Energy Production
- 2.93 x 10^{8} Kwh/Year Energy Production

FUEL	Btu
o Steam	6.7 x 10^{12}

LAND	Acres
o Permanent	31-62
o Undisturbed	250-290

COSTS	Dollars (1978)
o Construction	\$11.2 million
o Operation and Maintenance	\$ .2 million
o Fuel	\$3.8 - 5.2 million
o Pollution Abatement (capital + O and M) peroxide system ozone system	\$2.8 million

PERSONNEL	Workers/Year
o Construction	58
o Operation and Maintenance	5

BIOMASS

SYSTEM:

- o Wood materials/vegetation used as combustion material for firing a steam electric plant.

COMPONENTS

- o Steam generating equipment
- o Draft System
- o Wood fuel equipment
- o Ash handling system
- o Emission control equipment
- o Turbine generator equipment
- o Condenser water system
- o Cooling tower system
- o Switchgear
- o Protective equipment
- o Electric structure and wire contingency
- o Miscellaneous plant equipment

RESOURCES USED:

PLANT CHARACTERISTICS

- o 60 MW Plant Capacity
- o 80% Plant Factor
- o 30 Year Service Life
- o 32% Plant Efficiency
- o 1.34×10^{12} Btu/Year Energy Production
- o 2.93×10^{8} Kwh/Year Energy Production

FUEL	Dry-Tons
o Wood/Plant materials	1.87×10^{5}

LAND	Acres
o Storage/Plant site	75.0
o Landfill for boiler residue	.5

COSTS	Dollars
o Construction	N/A
o Operation and Maintenance	N/A
o Fuel	N/A

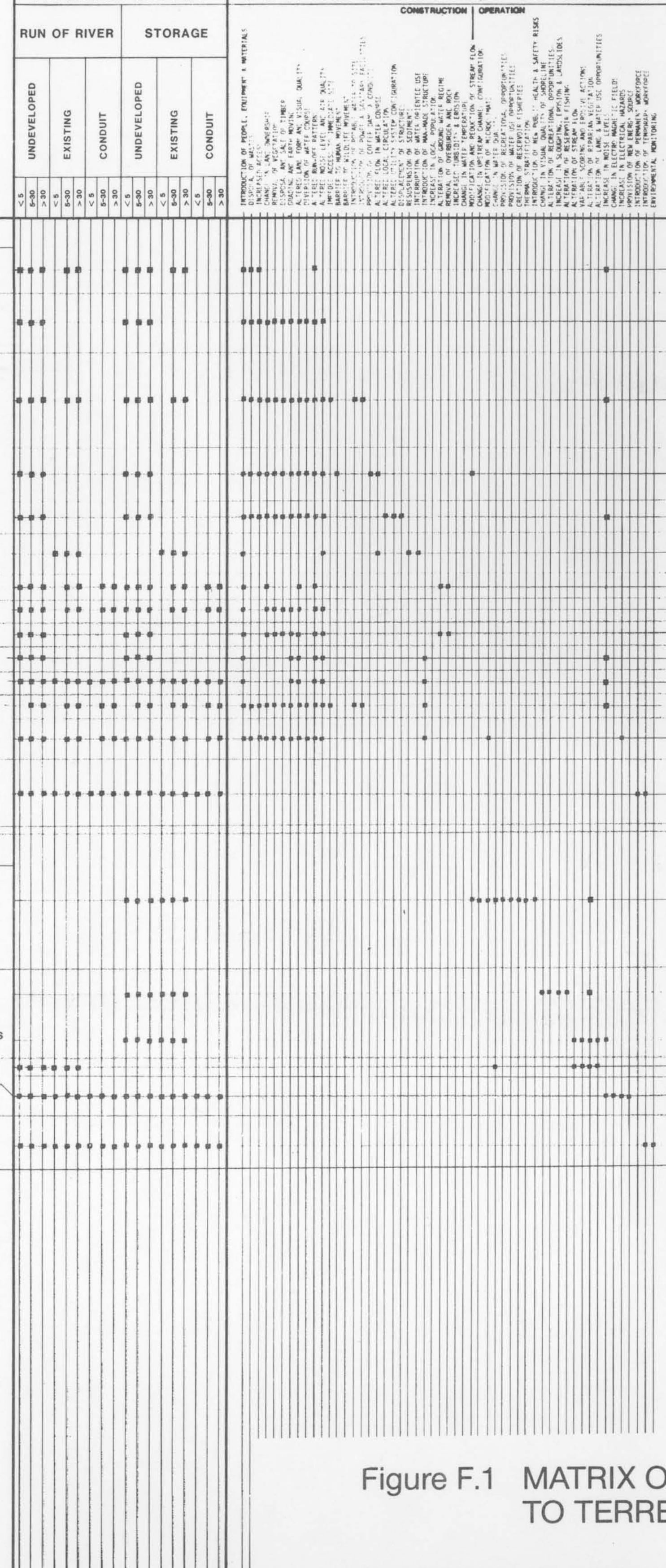
PERSONNEL	Workers/Year
o Construction	N/A
o Operation and Maintenance	22.4

☆ U.S. GOVERNMENT PRINTING OFFICE : 1983 O - 399-635

TERRESTRIAL ECOLOGY: POSSIBLE BENEFICIAL OR ADVERSE IMPACTS

▼ ADVERSE, LONG-TERM ● BENEFICIAL, LONG-TERM
▼ ADVERSE, SHORT-TERM ● BENEFICIAL, SHORT-TERM

DEFINITION OF HYDROPOWER (RUN OF RIVER: UNDEVELOPED, EXISTING, CONDUIT; STORAGE: UNDEVELOPED, EXISTING, CONDUIT; < 5, 5-30, > 30) — POTENTIAL CHANGED CONDITION (CONSTRUCTION | OPERATION)



ACTION	PRIMARY	SECONDARY	MITIGATION	KEY POLICY ISSUES
CONSTRUCTION				
A EXPLORATION	A_1 —— ▼ DISTURBANCE OF WILDLIFE DUE TO EXPLORATORY ACTIVITIES ▼ SOME LOSS OF VEGETATION	A_2 —— ▼ INCREASED RISK OF FIRE	A_3 —— o USE OF MUFFLER & SPARK ARRESTORS ON EQUIPMENT o CONTROL ACCESS	
B ACCESS ROADS	B_1 —— A_1 + ▼ LOSS OF RIPARIAN HABITAT ▼ LOSS OF PLANT SPECIES	B_2 —— A_2 + ▼ INCREASED TRAPPING & HUNTING	B_3 —— A_3 + o PROGRESSIVE REVEGETATION	
C SITE PREPARATION	C_1 —— ▼ POPULATION REDUCTIONS OF INDIGENOUS WILDLIFE ▼ LOSS OF TOPSOIL ORGANISMS ▼ LOSS OF PLANT SPECIES ▼ IMPACTS TO ENDANGERED SPECIES, IF PRESENT ▼ DISRUPTION OF MIGRATORY PATTERNS	C_2 —— A_2 + ▼ LOSS OF SCIENTIFIC & EDUCATIONAL VALUES RELATED TO ENDANGERED SPECIES	C_3 —— $A_3 + B_3$ + o PREPARE ENVIRONMENTAL-BASED SITE SELECTION AS PART OF FEASIBILITY STUDY	
D STREAM DIVERSION	D_1 —— ▼ LOSS OF RIPARIAN HABITAT ▼ LOSS OF RIVERINE WILDLIFE ▼ IMPACTS TO ENDANGERED SPECIES	D_2 —— C_2	D_3 —— C_3	
E RESERVOIR CLEARING	E_1 —— $C_1 + D_1$	E_2 —— $A_2 + C_2$ ▼ LOCAL LOSS OF HUNTING & TRAPPING	E_3 —— $A_3 + C_3$ + o DEVELOP HABITAT MANAGEMENT PLANS IN NEARBY AREAS FOR COMPENSATION	
F RESERVOIR DREDGING	F_1 —— ▼ LOSS OF RIPARIAN HABITAT o LOSS OF WATERBIRD HABITAT	F_2 —— ▼ LOSS OF WATER FOWL HUNTING	F_3 —— o DEVELOP WATER BIRD HABITAT WHERE FEASIBLE	
G EXCAVATION	G_1 —— C_1	G_2 —— $A_2 + C_2 + E_2$	G_3 —— $A_3 + C_3$	
H SPOILS AREA	H_1 —— C_1	H_2 —— $A_2 + C_2 + E_2$	H_3 —— $A_3 + C_3$	
I BORROW PITS (NOT WITHIN INUNDATED AREA)	I_1 —— C_1	I_2 —— $A_2 + C_2 + E_2$	I_3 —— $A_3 + C_3$	
J DAM CONSTRUCTION	J_1 —— C_1	J_2 —— $A_2 + C_2 + E_2$	J_3 —— $A_3 + C_3$	
K POWERHOUSE CONST. (IF REMOTE FROM DAM)	K_1 —— C_1	K_2 —— $A_2 + C_2 + E_2$	K_3 —— $A_3 + C_3$	
L SWITCHYARD CONST. (IF REMOTE FROM POWERHOUSE)	L_1 —— C_1	L_2 —— $A_2 + C_2 + E_2$	L_3 —— $A_3 + C_3$	
M TRANSMISSION LINES	M_1 —— C_1 + ▼ INCREASED PRESSURE ON HUNTING & TRAPPING	M_2 —— $A_2 + C_2 + E_2$	M_3 —— $A_3 + C_3$	
N ACCOMMODATION OF WORK FORCE	N_1 —— M_1	N_2 —— ▼ DISTURBANCE TO WILDLIFE BY WORKER'S PETS (DOGS, CATS)	N_3 —— o RESTRICT USE OF FIREARMS AND ENFORCE PET LEASH LAWS	
OPERATION				
A IMPOUNDMENT AND CREATION OF MAN-MADE LAKE	A_1 —— ▼ LOSS OF RIPARIAN HABITAT ▼ LOSS OF RIVERINE LIFE ▼ DISRUPTION OF MIGRATORY PATTERNS ▼ LOSS OF ENDANGERED SPECIES ▼ LOSS OF UNIQUE HABITAT ▼ LOSS OF TOPSOIL ORGANISMS ▼ LOSS OF WETLANDS ▼ TEMPORARY/PERMANENT LOSS OF WILD FOWL & RIVERINE HUNTING ▼ LOSS OF PLANTS SPECIES ● INCREASE HABITAT FOR WATER FOWL AND FISH-EATING RAPTORS	A_2 —— ● INCREASED WATER FOWL HUNTING ▼ LOSS OF TRAPPING REVENUES ▼ LOSS OF HUNTING ▼ LOSS OF WILDERNESS CHARACTERISTICS ● ▼ LOSS/GAIN OF SCIENTIFIC EDUCATION VALUES	A_3 —— o PURCHASE AND MANAGE SIMILAR AREAS ELSEWHERE o DEVELOP HABITAT MANAGEMENT PLAN FOR PROJECT AREA AS APPROPRIATE	
B TURBINE RELEASE a) RESERVOIR FLUCTUATIONS	Ba_1 —— ▼ DISPLACEMENT OF RIVERINE WILDLIFE ▼ ALTERATION OF RIPARIAN/WETLAND HABITAT	Ba_2 ——	Ba_3 ——	
b) DOWN STREAM FLUCTUATIONS	Bb_1 —— ▼ POTENTIAL ALTERATION OF RIPARIAN/WETLAND HABITAT ▼ POTENTIAL LOSS OF RIVERINE LIFE ▼ DISRUPTION OF WATER BIRD HABITAT	Bb_2 —— ▼ LOSS OF HUNTING & TRAPPING	Bb_3 —— o TIMING OF DAILY, SEASONAL AND YEARLY RELEASE REGIMES o ESTABLISH MINIMUM FLOW VOLUMES	
C SURFACE RELEASE	C_1 —— Bb_1 TO A LESSER EXTENT	C_2 ——	C_3 ——	
D POWER GENERATION	D_1 —— ▼ DISTURBANCE OF WILDLIFE ▼ POTENTIAL DISTURBANCE OF WATER FOWL	D_2 —— ▼ LOCALIZED LOSS OF HUNTING & TRAPPING	D_3 ——	
E MAINTENANCE	E_1 —— ▼ INCREASE IN HUNTING/TRAPPING	E_2 ——	E_3 —— o CONTROL ACCESS o MANAGE HUNTING ACTIVITY	

ources for Figures F.1- F.4: Ebel, 1976; BPA, 1976 and 1980; EDAW 1977 to 1980; George Washington Law Review, 1977; IWR, 1978; Hildebrand, 1979; Jones and Stokes, 1976; Loar et. al., 1980; NMFS, 1979; Oliver, 1975; Szluha et. al., 1979; DOE, 1978; Fish and Wildlife Service, Office of Biological Services, 1977a and c, 1978a to e, 1979a to c; Washington State Department of Game, 1976, 1977, and 1979

Figure F.1 MATRIX OF GENERIC HYDROPOWER IMPACTS RELATED TO TERRESTRIAL ECOLOGY

EDAW 8/80

ACTION	DEFINITION OF HYDROPOWER (RUN OF RIVER: UNDEVELOPED, EXISTING, CONDUIT; STORAGE: UNDEVELOPED, EXISTING, CONDUIT)	POTENTIAL CHANGED CONDITION (CONSTRUCTION / OPERATION)	WATER QUALITY/USE: POSSIBLE BENEFIC OR ADVERSE IMPACTS — PRIMARY	SECONDARY	MITIGATION	KEY POLICY ISSUES
CONSTRUCTION						
A EXPLORATION			A_1 —— ▼ POTENTIAL SURFACE WATER DEGRADATION FROM MACHINERY & HUMAN WASTES	A_2 —— ▼ INCREASED FIRE HAZARD ▼ LOSS OF WILDERNESS CHARACTER	A_3 —— o STRICT CONTROLS ON DISPOSAL OF WASTES o SPARK ARRESTORS ON EQUIPMENT	
B ACCESS ROADS			B_1 —— A_1, PLUS ▼ INCREASED EROSION, TURBIDITY & SEDIMENTATION	B_2 —— ● INCREASED OPPORTUNITY FOR RECREATIONAL USE ▼ INCREASED PRESSURE FOR HUNTING & FISHING ▼ POTENTIAL SURFACE WATER POLLUTION DUE TO INCREASED HUMAN ACTIVITY ▼ DEGRADATION OF SPORT FISHING	B_3 —— o CONTROLLED ACCESS o ALIGNMENT OF ROADS TO MINIMIZE IMPACTS o PROGRESSIVE REVEGETATION OF DISTURBED AREAS o CONSTRUCT WATER BARS AND ENERGY DISSIPATORS AT FREQUENT INTERVALS	
C SITE PREPARATION			C_1 —— B_1 + ▼ POTENTIAL SURFACE WATER DEGRADATION FROM MACHINERY WASTES	C_2 —— ▼ LOSS OF WILDERNESS CHARACTER ▼ LOSS OF WATER USE IN IMPEDED AREA ▼ LOSS OF PUBLIC ACCESS TO FISHING AND RECREATION ▼ IF LARGE SCALE HYDRO PLANT, SOME DEGRADATION OF FISHERIES	C_3 —— o EROSION CONTROL BY —— MULCH, NETTING, SEEDING o CONSTRUCT SETTLING PONDS	
D STREAM DIVERSION			D_1 —— C_1 + B_1 + ▼ CHANGE IN WATER TEMPERATURE ▼ SCOURING AT OUTFALL ▼ ALTERED STREAM VELOCITY	D_2 —— ▼ INTERRUPTION FISHING & RECREATIONAL USES ▼ POTENTIAL INTERRUPTION OF NAVIGATIONAL CHANNEL ▼ TEMPORARY LOSS OF SHIPPING REVENUES ON DAM GREATER THAN 30 MW	D_3 —— o CONSTRUCT SETTLING PONDS o CONSTRUCT STILLING BASIN AT OUTFALL	
E RESERVOIR CLEARING			E_1 —— B_1 + C_1 + ▼ NUTRIENT BUILD-UP ▼ ALTERED RUNOFF	E_2 —— ▼ LOSS OF PUBLIC ACCESS	E_3 —— o SELECTIVE CLEARING o NO CLEARING o CONSTRUCT SETTLING PONDS	
F RESERVOIR DREDGING			F_1 —— C_1 + ▼ RELEASE OF SEDIMENTO ODORS ▼ RESUSPENSION OF SEDIMENTS ▼ POSSIBLE RELEASE OF HEAVY METAL, PESTICIDE, HERBICIDES & OTHER TOXIC MATERIALS S ▼ INCREASED TURBIDITY ▼ CHANGE IN WATER TEMPERATURE ▼ LOSS OF WETLANDS	F_2 —— ▼ LOSS OF HUNTING & FISHING ▼ LOSS OF RESERVOIR RECREATION DUE TO DRAINING OF RESERVOIR ▼ POTENTIAL TEMPORARY LOSS OF IRRIGATION WATER ▼ POTENTIAL LOSS OF POTABLE WATER AND COST OF ALTERNATE WATER SUPPLY	F_3 —— o NUTRIENT INACTIVATION BY CHEMICAL IMMOBILIZATION o TYPE OF DREDGE, e.g., SUCTION o TEMPORARY DAMS o SEASONAL DREDGING	
G EXCAVATION			G_1 —— B_1 (IF NEAR WATER COURSE) + C_1	G_2 —— ▼ DISRUPTION OF LOCAL RECREATIONAL ACTIVITIES IF ADJACENT TO WATER COURSE	G_3 —— o REVEGETATION o TIMING OF BLASTING	
H SPOILS AREA			H_1 —— ▼ POTENTIAL CONTAMINATION OF SURFACE WATER FROM RUNOFF ▼ POTENTIAL CONTAMINATION OF GROUNDWATER FROM LEACHING	H_2 —— ▼ INCREASED COST OF WATER TREATMENT	H_3 —— o REGULATION OF SPOILS PLACEMENT o LIME DISPOSAL AREA WITH IMPERVIOUS LAYER o NUTRIENT INACTIVATION BY CHEMICAL IMMOBILIZATION o RECLAMATION PLAN	
I BORROW PITS (NOT WITHIN INUNDATED AREA)			I_1 —— A_1 + B_1 (IF NEAR WATER)	I_2 —— G_2 ● POUNDING & POTENTIAL RECREATIONAL USE	I_3 —— G_3 + o CONSTRUCT SEDIMENT TRAPS	
J DAM CONSTRUCTION			J_1 —— C_1 +	J_2 ——	J_3 —— o STRICT CONTROL ON DISPOSAL OF WASTES	
K POWERHOUSE CONST. (IF REMOTE FROM DAM)			K_1 —— B_1	K_2 —— ▼ LOSS IN RECREATIONAL USE	K_3 —— o CONSTRUCT SEDIMENT TRAPS o REVEGETATE	
L SWITCHYARD CONST. (IF REMOTE FROM POWERHOUSE)			L_1 —— ▼ INCREASED EROSION TURBIDITY & SEDIMENTATION IF NEAR WATER SOURCE ▼ POTENTIAL POLLUTION FROM HUMAN & MACHINERY WASTES	L_2 —— ▼ POTENTIAL TEMPORARY LOSS OF RECREATIONAL USE ▼ LOSS OF ACCESS TO IMMEDIATE AREA	L_3 —— o PROGRESSIVE REVEGETATION o CONSTRUCT SETTLING PONDS o SITE SELECTION TO MINIMIZE IMPACTS	
M TRANSMISSION LINES			M_1 —— L_1+ o IF R.O.W. PARALLEL TO WATER COURSE	M_2 —— ▼ INCREASED PUBLIC USE OF REMOTE AREAS ADJACENT TO R.O.W.	M_3 —— o PROGRESSIVE REVEGETATION o ALIGNMENT OF R.O.W. TO MINIMIZE IMPACTS	
N ACCOMMODATION OF WORK FORCE			N_1 —— ▼ INCREASED DEMAND FOR WATER USE & WASTE FACILITIES	N_2 —— ▼ POTENTIAL CONFLICT WITH EXISTING WATER USERS	N_3 —— o PROVISION OF SANITARY FACILITIES o PROVISION OF POTABLE WATER SUPPLY	
OPERATION						
A IMPOUNDMENT AND CREATION OF MAN-MADE LAKE			A_1 —— ▼ CHANGE FROM RIVERINE TO LACUSTERINE ENVIRONMENT ▼ DAILY, SEASONAL & YEARLY DOWNSTREAM FLUCTUATIONS ▼ INCREASED EVAPORATION RATE ▼ RESERVOIR SILTATION ▼ THERMAL STRATIFICATION, IF DEEP RESERVOIR ▼ DECREASED CONCENTRATION OF DISSOLVED O_2 IN HYPOLIMNION ▼ SPRING & FALL TURNOVER RESULTS IN SURGES OF SALTS, NUTRIENTS & OTHER MATERIALS ▼ INCOMPLETE MIXING ▼ POTENTIAL FOR EUTROPHICATION	A_2 —— ▼ LOSS OF WHITEWATER RECREATION, EMPLOYMENT & INCOME ● POTENTIAL FOR FLATWATER RECREATION ● INCREASED AVAILABILITY OF WATER TO SURROUNDING AGRICULTURAL AREAS ● POTENTIAL FOR DEVELOPMENT AROUND RESERVOIR ● POTENTIAL FOR BOTH COLD & WARM WATER FISHERIES ● POTENTIAL FLOOD CONTROL FACILITY ▼ PERIODIC DREDGING ● INCREASED REVENUE FROM FISHERIES ● POTENTIAL INCREASE IN REVENUE FROM FLATWATER RECREATION EMPLOYMENT ▼ POTENTIAL PUBLIC SAFETY RISK FROM DAM FAILURE IF IN SEISMIC ZONE ▼ CHANGE TO WARMWATER FISH SPECIES IN LARGE SCALE STORAGE RESERVOIRS	A_3 —— o ESTABLISH DOWNSTREAM FLOW REGIMES o SEASONAL FILLING OF RESERVOIR o LONG TERM FILLING OF RESERVOIR o GROWTH MANAGEMENT PLAN o SELECTIVE CLEARING o DESTRATIFICATION & HYPOLIMNOTIC AERATION	
B TURBINE RELEASE a) RESERVOIR FLUCTUATIONS			Ba_1 —— ▼ LOSS OF VEGETATION IN DRAWDOWN ZONE & EXPOSURE OF SHORELINE ▼ INCREASED SLOUGHING, EROSION & LANDSLIDES ▼ INCREASED TURBIDITY ▼ NUTRIENT MOVED TO DEEPER WATER ▼ RESUSPENSION & REDISTRIBUTION OF BANK SEDIMENTS ▼ DECREASE IN LIGHT TRANSMISSIVITY ▼ NUTRIENT LOADING	Ba_2 —— ▼ DISRUPTION AND/OR DEGRADATION OF SHORELINE ACTIVITIES ▼ SOME LOSS OF RECREATIONAL FISHING ▼ BOATING & SWIMMING HAZARDS ▼ LOSS OF FISH PRODUCTION	Ba_3 —— o INUNDATE RESERVOIR WITHOUT CLEARING o INSTALLATION OF FLOATING DOCKS o ESTABLISH DRAWDOWN REQUIREMENTS o USE OF RIPRAP, CONCRETE INJECTIONS, ETC., TO CONTROL BANK SLOGHING o SCHEDULING DRAWDOWN TO MINIMIZE IMPACTS TO THE FISHERY	
b) DOWN STREAM FLUCTUATIONS			Bb_1 —— ▼ DOWNSTREAM TEMPERATURE FLUCTUATIONS ▼ EROSION & SCOURING OF BANKS ▼ DEWATERING OF STREAM SEGMENTS DURING LOW FLOW CYCLE ▼ SUDDEN INCREASES IN WATER VOLUME & VELOCITY ▼ COLD WATER WITH LOW DISSOLVED OXYGEN WATER RELEASES	Bb_2 —— ▼ DISRUPTION OF RECREATIONAL ACTIVITIES ▼ LOSS OF WATER TO USERS DUE TO DEWATERING ▼ POTENTIAL LOSS OF SUITABLE (FISHERY) WATER TEMPERATURES	Bb_3 —— o DESTRATIFICATION & HYPOLIMNOTIC AERATION o ESTABLISH DOWNSTREAM FLOW REGIMES o AERATION DEVICE AT OUTLET	
C SURFACE RELEASE			C_1 —— ▼ INCREASED NITROGENT CONTENT ▼ WARM WATER RELEASE ▼ ALTERATION OF WATER TEMPERATURE	C_2 —— ▼ LOSS OF COMMERCIAL FISHERIES	C_3 —— o SPILLWAY DEFLECTORS	
D POWER GENERATION			D_1 —— o SEE LAND USE & TERRESTRIAL IMPACT TABLES	D_2 ——	D_3 ——	
E MAINTENANCE			E_1 —— ▼ INCREASED NEED FOR POTABLE WATER & SANITARY FACILITIES	E_2 ——	E_3 —— o PROVISION OF TEMPORARY OR PERMANENT FACILITIES	

Legend: ▼ ADVERSE, LONG-TERM ● BENEFICIAL, LONG-TERM ▼ ADVERSE, SHORT-TERM ● BENEFICIAL, SHORT-TERM

Figure F.2 MATRIX OF GENERIC HYDROPOWER IMPACTS RELATED TO WATER QUALITY AND USE

EDAW 8/80

AQUATIC ECOLOGY: POSSIBLE BENEFICIAL OR ADVERSE IMPACTS

▼ ADVERSE, LONG-TERM ● BENEFICIAL, LONG-TERM
▼ ADVERSE, SHORT-TERM ● BENEFICIAL, SHORT-TERM

ACTION	PRIMARY	SECONDARY	MITIGATION	KEY POLICY ISSUES
CONSTRUCTION				
A EXPLORATION	A_1 —— ▼ MINOR DISRUPTION OF STREAM FLOWS	A_2 —— ● INCREASE IN PUBLIC ACCESS	A_3 —— o CONTROL ACCESS	
B ACCESS ROADS	B_1 —— ▼ ALTERATION IN STREAM FLOWS ▼ LOSS OF RIPARIAN EDGE ▼ DISRUPTION OF SPAWNING BEDS (SEDIMENTATION & PHYSICAL DISRUPTION) ▼ DISRUPTION OF BENTHIC ECOLOGY ● INCREASE IN COLDWATER RECREATIONAL FISHING	B_2 —— ▼ INCREASED PRESSURE FOR RECREATIONAL FISHING -TROUT, SALMON, BASS, CRAPPIE	B_3 —— o ALIGNMENT OF ROADS TO MINIMIZE IMPACTS o CONSTRUCT SEDIMENT TRAPS o CONTROL ACCESS o PROGRESSIVE RECLAMATION	
C SITE PREPARATION	C_1 —— B_1 MINUS INCREASE IN COLDWATER FISHING	C_2 —— ▼ LOSS OF PUBLIC ACCESS TO LOCAL FISHING GROUNDS	C_3 —— o CONSTRUCT SEDIMENT TRAPS o SELECTIVE CLEARING o PROGRESSIVE REVEGETATION	
D STREAM DIVERSION	D_1 —— ▼ LOSS OF BENTHIC ECOLOGY ▼ LOSS OF SPAWNING BEDS ▼ LOSS OF RIPARIAN EDGE ▼ BLOCKING OF ANADROMOUS FISH RUN	D_2 —— ▼ LOSS OF INCOME & EMPLOYMENT FROM COMMERCIAL & RECREATIONAL FISHING	D_3 —— o TRANSPORTATION OF FISH	
E RESERVOIR CLEARING	E_1 —— B_1	E_2 —— D_2	E_3 —— o SELECTIVE CLEARING o NO CLEARING	
F RESERVOIR DREDGING	F_1 —— D_1 MINUS BLOCKING OF ANADROMOUS FISH	F_2 —— ▼ TEMPORARY LOSS OF INCOME & EMPLOYMENT FROM RECREATIONAL FISHING	F_3 ——	
G EXCAVATION	G_1 —— ▼ DISRUPTION OF SPAWNING BEDS ▼ DISRUPTION OF BENTHIC ECOLOGY	G_2 ——	G_3 —— o CONSTRUCT SEDIMENT TRAPS	
H SPOILS AREA	H_1 ——	H_2 ——	H_3 ——	
I BORROW PITS (NOT WITHIN INUNDATED AREA)	I_1 ——	I_2 ——	I_3 —— o OPPORTUNITY FOR CREATING FISHERY-RELATED RECREATION	
J DAM CONSTRUCTION	J_1 —— ▼ DISRUPTION OF WARMWATER FISHING	J_2 —— D_2	J_3 ——	
K POWERHOURE CONST (IF REMOTE FROM DAM)	K_1 ——	K_2 —— ● INCREASE IN LOCAL RECREATIONAL FISHING	K_3 —— o CONTROL ACCESS	
L SWITCH YARD CONST (IF REMOTE FROM POWERHOUSE)	L_1 ——	L_2 ——	L_3 ——	
M TRANSMISSION LINES	M_1 —— IF PARALLELING A WATER COURSE ▼ DISRUPTION OF BENTHIC ECOLOGY ▼ DISRUPTION OF RIPARIAN EDGE ▼ DISRUPTION OF SPAWNING BEDS ● INCREASE PUBLIC ACCESS	M_2 —— ▼ INCREASED PRESSURE ON RECREATIONAL FISHING - TROUT, SALMON, BASS, CRAPPIE, SUNFISH	M_3 —— J_3 o CONSTRUCT SEDIMENT TRAPS o EFFECTIVE REVEGETATION OF EXPOSED SOIL	
N ACCOMMODATION OF WORK FORCE	N_1 —— ▼ INCREASED PRESSURE ON RECREATIONAL FISHING CRAPPIE, SUNFISH	N_2 ——	N_3 ——	
OPERATION				
A IMPOUNDMENT AND CREATION OF MAN-MADE LAKE	A_1 —— ● CREATION OF DOWNSTREAM COLDWATER FISHERY PRODUCTION ● INCREASE IN FLATWATER FISHING ▼ LOSS OF ANADROMOUS FISHING ▼ LOSS OF RIVER FISHERIES ▼ LOSS OF RIVERINE BENTHIC ECOLOGY ▼ LOSS OF RIPARIAN EDGE ▼ LOSS OF SPAWNING BEDS IN INUNDATED RIVER ▼ INCREASE IN WARM WATER FISHING ▼ LOSS OF ENDANGERED SPECIES	A_2 —— ● INCREASE IN WARM WATER FISHING - BASS, CRAPPIE, SUNFISH ▼ LOSS OF INCOME FROM COLD WATER COMMERCIAL FISHING ● INCREASE IN PRIMARY & SECONDARY INCOME FROM RECREATIONAL FISHING ▼ LOSS OF SCIENTIFIC & EDUCATIONAL VALUES ▼ INCREASED PREDATION ON JUVENILE SALMON	A_3 —— o TRANSPORTATION OF FISH o FISH LADDERS o STOCKING PROGRAMS o ESTABLISH SUITABLE DOWNSTREAM FLOW REGIMES	
B TURBINE RELEASE a) RESERVOIR FLUCTUATIONS	Ba_1 —— ▼ LOSS OF WARM WATER SPAWNING BEDS ▼ LOSS OF BENTHIC HABITAT ▼ LOSS OF RIPARIAN EDGE	Ba_2 —— ▼ LOSS IN RECREATIONAL FISHING	Ba_3 —— o SCHEDULE FLUCTUATIONS TO MINIMIZE IMPACTS ON FISH REPRODUCTION	
b) DOWN STREAM FLUCTUATIONS	Bb_1 —— Ba_1 MINUS LOSS OF WARM WATER SPAWNING BEDS + ▼ 7 TO 30% FISH MORTALITY DUE TO TURBINE PASSAGE ▼ LOSS OF SPAWNING, REARING, AND FOOD PRODUCING FISH HABITAT ▼ LOSS OF RECREATIONAL COLD WATER FISHING ▼ LOSS OF ADULT FISH DUE TO DELAYS IN UPSTREAM PASSAGE	Bb_2 —— ▼ LOSS OF SECONDARY EMPLOYMENT & INCOME FROM RECREATIONAL FISHING ▼ LOSS OF COMMERCIAL FISHING INCOME & EMPLOYMENT	Bb_3 —— o ESTABLISH WARM AND COLD WATER FISH HATCHERIES o DEVELOP FISH BYPASS OR TRANSPORT SYSTEMS o SPILL WATER DURING JUVENILE MIGRATION o CONTROL TURBINE LOADING DURING ADULT MIGRATION	
C SURFACE RELEASE	C_1 —— ▼ LOSS OF FISH DUE TO NITROGEN NARCOSIS (GAS BUBBLE DISEASE) ▼ LOSS OF FISH & RIPARIAN HABITAT THROUGH SCOURING OF THE STREAM CHANNEL	C_2 —— Bb_2	C_3 ——	
D POWER GENERATION	D_1 ——	D_2 ——	D_3 ——	
E MAINTENANCE	E_1 ——	E_2 ——	E_3 ——	

DEFINITION OF HYDROPOWER: RUN OF RIVER (UNDEVELOPED, EXISTING, CONDUIT); STORAGE (UNDEVELOPED, EXISTING, CONDUIT); < 5, 5-30, > 30

POTENTIAL CHANGED CONDITION: CONSTRUCTION \| OPERATION

Figure F.3 MATRIX OF GENERIC HYDROPOWER IMPACTS RELATED TO AQUATIC ECOLOGY

EDAW 8/80

LAND USE: POSSIBLE BENEFICIAL OR ADVERSE IMPACTS

▼ ADVERSE, LONG-TERM ● BENEFICIAL, LONG-TERM
▼ ADVERSE, SHORT-TERM ● BENEFICIAL, SHORT-TERM

DEFINITION OF HYDROPOWER: RUN OF RIVER (UNDEVELOPED, EXISTING, CONDUIT); STORAGE (UNDEVELOPED, EXISTING, CONDUIT)

POTENTIAL CHANGED CONDITION: CONSTRUCTION | OPERATION

ACTION	PRIMARY	SECONDARY	MITIGATION	KEY POLICY ISSUES
CONSTRUCTION				
A EXPLORATION	A_1 — ▼ INCREASED PUBLIC USE DUE TO ACCESS	A_2 — ▼ LOSS OF WILDERNESS CHARACTERISTICS AND VALUES ▼ RISK OF FIRE	A_3 — o USE OF EQUIPMENT MUFFLERS & SPARK ARRESTORS o SPRAYING TO REDUCE DUST o REVEGETATION OF ACCESS ROUTES	
B ACCESS ROADS	B_1 — ▼ INCREASE IN LOCAL NOISE LEVEL ▼ INCREASE IN LOCAL TRAFFIC CONGESTION ▼ INCREASE IN AIRBORNE PARTICULATE MATTER	B_2 — ● INCOME FROM SALE OF TIMBER ▼ LOSS OF WILDERNESS RECREATION VALUES ▼ INCREASED HUNTING AND RECREATIONAL ACTIVITIES DUE TO ACCESS ▼ IMPAIRED QUALITY OF LIFE IN ADJACENT COMMUNITIES DUE TO NOISE, TRAFFIC AND DUST ▼ INCREASE OF FIRE RISK	B_3 — o ALIGNMENT SELECTED TO MINIMIZE IMPACTS o COMPENSATION TO FARMERS & LAND OWNERS o CONTROLLED ACCESS o REVEGETATION o SPRAYING TO REDUCE DUST o USE OF EQUIPMENT MUFFLERS & SPARK ARRESTORS	
C SITE PREPARATION	C_1 — B_1	C_2 — ▼ INCREASED FIRE RISK ● INCOME FROM SALE OF TIMBER ▼ LOSS OF WILDERNESS RECREATION VALUES ▼ LOSS OF ON-SITE RECREATIONAL ACTIVITY ▼ IMPAIRED QUALITY OF LIFE IN ADJACENT COMMUNITIES DUE TO NOISE, TRAFFIC AND DUST	C_3 — o SPRAYING TO REDUCE DUST o USE OF EQUIPMENT MUFFLERS & SPARK ARRESTORS o CONTROL OF EROSION & RUN-OFF	
D STREAM DIVERSION	D_1 — B_1 + ▼ IMPEDIMENT TO FISH MIGRATION ▼ LOSS OF INCOME AND EMPLOYMENT DUE TO LOSS OF FISHERIES ▼ LOCAL LOSS OF WATER-BASED RECREATION ACTIVITIES ▼ LOSS OF NAVIGATION ROUTE IF ON LARGE, DEEP RIVER	D_2 — ▼ ECONOMIC LOSS TO LOCAL COMMUNITIES DUE TO LOSS OF RECREATIONAL & FISHERY ACTIVITIES ▼ COST OF ALTERNATE SHIPPING ROUTE ▼ IMPAIRED QUALITY OF LIFE IN ADJACENT COMMUNITIES DUE TO NOISE, TRAFFIC & DUST; MAJOR IMPACT IF A LARGE DAM PROJECT IS SITED NEAR A COMMUNITY	D_3 — C_3 + o MAINTENANCE OF ESTABLISHED MINIMUM FLOWS o CREATION OF ALTERNATE SHIPPING ROUTES o CONSTRUCTION OF FISH LADDERS	
E RESERVOIR CLEARING	E_1 — B_1 + ▼ LOSS OF EXISTING & POTENTIAL MINING, AGRICULTURAL, TIMBER & RECREATIONAL RESOURCES & FACILITIES ▼ REMOVAL OR LOSS OF RESIDENCES & SECOND HOMES ▼ LOSS OF INCOME & EMPLOYMENT DUE TO LOSS OF FISHERIES	E_2 — C_2 + ▼ ECONOMIC LOSS TO LOCAL COMMUNITIES DUE TO LOSS OF EXISTING RESOURCE-BASED ACTIVITIES ▼ DECLINE IN LOCAL HOUSING SUPPLY ▼ LOSS OF LOCAL TAX REVENUES ▼ PUBLIC AND PRIVATE COSTS OF RELOCATION OF POPULATION AND REALIGNMENT OF ROADS AND UTILITIES ▼ IMPACT OF RELOCATION ON POPULATION ▼ LOSS OF SCIENTIFIC, EDUCATIONAL AND HISTORIC VALUES ASSOCIATED WITH ARCHAEOLOGIC & CULTURAL RESOURCES ▼ RISK OF FIRE ● POSSIBLE USE OF LOCAL LABOR FORCE	E_3 — o CONTROL OF EROSION & RUN-OFF o SPRAYING TO REDUCE DUST o USE OF EQUIPMENT MUFFLERS o COMPENSATION o EQUIPMENT SPARK ARRESTORS	
F RESERVOIR DREDGING	F_1 — ▼ INCREASE IN LOCAL NOISE LEVEL ▼ ODOR OF DREDGE SPOILS ▼ LOSS OF INCOME & EMPLOYMENT DUE TO LOSS OF FISHERIES ▼ CONTAMINATION OF POTABLE WATER ▼ DEGRADATION OF WATER-BASED RECREATIONAL ACTIVITIES	F_2 — ▼ IMPAIRED QUALITY OF LIFE IN ADJACENT COMMUNITIES DUE TO NOISE AND ODOR ▼ ECONOMIC LOSS TO LOCAL COMMUNITIES DUE TO LOSS OF RECREATION & FISHING ACTIVITIES ▼ COST OF ALTERNATE WATER SUPPLY	F_3 — o EQUIPMENT SPARK ARRESTORS o USE OF EQUIPMENT MUFFLERS o SEASONAL DREDGING o TYPE OF DREDGE, I.E., SUCTION, ETC. o TEMPORARY DAMS	
G EXCAVATION	G_1 — ▼ INCREASE IN NOISE LEVELS & PERCUSSIVE NOISE FROM BLASTING ▼ INCREASED AIRBORNE PARTICULATE MATTER ▼ INCREASE IN LOCAL TRAFFIC CONGESTION	G_2 — ▼ IMPAIRED QUALITY OF LIFE IN ADJACENT COMMUNITIES DUE TO NOISE, TRAFFIC & DUST ● INCOME FROM SALE OF OVERBURDEN AND ROCK	G_3 — o PROPER TIMING OF BLASTS o USE OF EQUIPMENT MUFFLERS o SPRAYING TO REDUCE DUST	
H SPOILS AREA	H_1 — B_1 + ▼ CONTAMINATION OF GROUNDWATER ▼ CONTAMINATION OF ADJACENT SOILS	H_2 — ● INCOME FROM SALE OF TIMBER ▼ LOSS OF USE OF AGRICULTURAL, TIMBER, MINING & RECREATIONAL RESOURCES AT SPOILS SITE ▼ IF SIGNIFICANT LOSS OF AESTHETIC VALUES OR LAND USE, DECLINE IN ADJACENT PROPERTY VALUES ▼ COST OF ALTERNATE WATER SOURCES ▼ VISUAL IMPACT DUE TO LANDSCAPE CHANGE	H_3 — o CHEMICAL TREATMENT OF TOXIC SPOILS o LINING DISPOSAL SITE WITH IMPERVIOUS MATERIALS	
I BORROW PITS (NOT WITHIN INUNDATED AREA)	I_1 — B_1 + ▼ CONVERSION OF EXISTING LAND USES	I_2 — ▼ IF LARGE SITE, LOSS OF INCOME & PROPERTY VALUES FROM AGRICULTURE, TIMBER, MINING & RECREATIONAL ACTIVITIES ▼ IMPAIRED QUALITY OF LIFE IN ADJACENT COMMUNITIES DUE TO TRAFFIC, NOISE, DUST AND VISUAL DEGRADATION ● INCOME FROM SALE OF OVERBURDEN, ROCK & TIMBER ▼ RISK OF FIRE	I_3 — o SITE SELECTION TO MINIMIZE IMPACTS o TIMING OF BLASTS o USE OF EQUIPMENT MUFFLERS AND SPARK ARRESTORS o SPRAYING TO REDUCE DUST o REVEGETATION o COMPENSATION	
J DAM CONSTRUCTION	J_1 — B_1 + ▼ VISUAL IMPAIRMENT ▼ DISRUPTION OF HUNTING, RECREATION & FISHING DURING CONSTRUCTION	J_2 — ▼ IMPAIRED QUALITY OF LIFE IN ADJACENT COMMUNITIES DUE TO NOISE, DUST & TRAFFIC ▼ ECONOMIC LOSS TO LOCAL COMMUNITIES DUE TO LOSS OF HUNTING, RECREATION & FISHING ACTIVITIES ▼ LOSS OF AESTHETIC VALUES DUE TO VISUAL IMPAIRMENT	J_3 — o USE OF EQUIPMENT MUFFLERS AND SPARK ARRESTORS o SPRAYING TO REDUCE DUST o CONTROL OF EROSION AND RUNOFF	
K POWERHOUSE CONST. (IF REMOTE FROM DAM)	K_1 — B_1 + ▼ CONVERSION OF EXISTING LAND USES ▼ VISUAL IMPAIRMENT	K_2 — B_2 + ▼ LOSS OF AESTHETIC VALUES DUE TO VISUAL IMPAIRMENT ▼ LOCAL INCREASE IN RECREATIONAL FISHING ▼ IF LARGE SCALE DAM, LOSS OF INCOME & PROPERTY VALUES DUE TO LOSS OF AESTHETIC VALUES AND LAND LOSS	K_3 — o SITE SELECTION TO MINIMIZE IMPACTS o USE OF EQUIPMENT MUFFLERS AND SPARK ARRESTORS o SPRAYING TO REDUCE DUST o REVEGETATION o COMPENSATION	
L SWITCHYARD CONST (IF REMOTE FROM POWERHOUSE)	L_1 — B_1 + ▼ CONVERSION OF EXISTING LAND USES ▼ VISUAL IMPAIRMENT	L_2 — K_2	L_3 — K_3	
M TRANSMISSION LINES	M_1 — B_1 + ▼ LOSS OF EXISTING LAND USES ALONG ROUTE ▼ VISUAL AND PHYSICAL IMPAIRMENT ▼ LOSS OF WILDERNESS CHARACTER	M_2 —	M_3 — o ALIGNMENT TO MINIMIZE IMPACT o REVEGETATION o USE OF EQUIPMENT MUFFLERS AND SPARK ARRESTORS o SELECTIVE TYPE OF TOWER CONFIGURATION o COMPENSATION	
N ACCOMMODATION OF WORK FORCE	N_1 — ▼ INCREASED DEMAND FOR LOCAL SERVICES AND HOUSING ▼ INCREASED DEMAND FOR POTABLE AND CONSTRUCTION-RELATED WATER	N_2 — ▼ IF LARGE DAM, CONFLICTS WITH EXISTING WATER USERS ● EMPLOYMENT OF LOCAL CONSTRUCTION WORK FORCE ▼ IF NO ON-SITE HOUSING, INCREASE IN COST OF EXISTING HOUSING OR CONSTRUCTION OF NEW HOUSING ● REDUCED UNEMPLOYMENT ● INCREASED LOCAL SECONDARY EMPLOYMENT & INCOME ▼ INCREASED PUBLIC COSTS	N_3 — o PROVISION OF ADEQUATE SANITARY FACILITIES AND HOUSING	
OPERATION				
A IMPOUNDMENT AND CREATION OF MAN-MADE LAKE	A_1 — ▼ LOSS OF EXISTING RECREATIONAL ACTIVITIES FOR UNDERDEVELOPED SITES ● INCREASE IN FLAT WATER RECREATIONAL ACTIVITIES ● INCREASE IN LOCAL WATER AVAILABILITY ▼ ALTERATION OF EXISTING FISHERIES	A_2 — ▼ LOSS OF WHITE-WATER RECREATIONAL ACTIVITIES & ASSOCIATED INCOME ▼ LOSS OF ARCHAEOLOGIC, CULTURAL, AGRICULTURAL, TIMBER & MINING RESOURCES & ASSOCIATED VALUES ▼ LOSS OF RECREATIONAL USE OF EXISTING SHORELINE ● INCREASED INCOME & EMPLOYMENT ASSOCIATED WITH FLAT-WATER RECREATION ● INCREASED AGRICULTURAL IRRIGATION & ASSOCIATED REVENUE ● INCREASED PROPERTY VALUE ON ADJACENT LANDS ● INCREASED DEVELOPMENT POTENTIAL OF ADJACENT LANDS ▼ INCREASED DEVELOPMENT ON DOWNSTREAM FLOODPLAINS ▼ INCREASED POTENTIAL DAMAGE DUE TO DAM FAILURE	A_3 — o CREATION OF FLATWATER RECREATIONAL FACILITIES o GROWTH MANAGEMENTS PLANS o MAINTENANCE OF DOWNSTREAM FLOW	
B TURBINE RELEASE a) RESERVOIR FLUCTUATIONS	Ba_1 — ▼ DEGRADATION OF WATER QUALITY DUE TO TURBIDITY ▼ LOSS OF RECREATIONAL ACTIVITIES ON EXISTING SHORELINES	Ba_2 — ▼ DEGRADATION OF EXISTING FISHERIES ▼ LOSS OF RECREATIONAL USERS & ASSOCIATED INCOME & EMPLOYMENT ▼ DECLINE IN SHORELINE PROPERTY-LINE VALUES ▼ COST OF CONSTRUCTION OF FLOATING BOAT DOCKS, COST OF ALTERATION OF EXISTING STRUCTURES	Ba_3 — o RIP-RAP OF SHORELINE o TIMED OR CONTROLLED FLUCTUATIONS o RESTOCKING OF FISHERIES	
b) DOWN STREAM FLUCTUATIONS	Bb_1 — ▼ DEWATERING OF STREAM SEGMENTS	Bb_2 — ▼ DISRUPTION OF IN-STREAM RECREATIONAL ACTIVITIES & INCOME & EMPLOYMENT o LOSS OF COMMERCIAL FISHERIES AND ASSOCIATED INCOME & EMPLOYMENT	Bb_3 — o TIMED & GRADUAL WATER FLUCTUATIONS	
C SURFACE RELEASE	C_1 — ▼ INCREASE IN WARM WATER FISH SPECIES	C_2 — ▼ DECREASE IN COLD WATER SPORT & COMMERCIAL FISH SPECIES	C_3 — o FISH STOCKING PROGRAM	
D POWER GENERATION	D_1 — o SEE TERRESTRIAL IMPACTS	D_2 — ▼ LOSS OF EXISTING HUNTING, TRAPPING & RECREATIONAL ACTIVITIES DUE TO NOISE ● INCREASED DEVELOPMENT POTENTIAL IN RECEIVING AREAS DUE TO INCREASED POWER AVAILABILITY	D_3 — o GROWTH MANAGEME PLANS	
E MAINTENANCE	E_1 — ▼ INCREASE IN WASTE AND DEMAND FOR POTABLE WATER	E_2 — ▼ COST OF PROVIDING WATER, POWER & ON-SITE FACILITIES	E_3 —	

EDAW 8/80

Figure F.4 MATRIX OF GENERIC HYDROPOWER IMPACTS RELATED TO LAND USE

IWR 82-H-8